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The Genesis of Petroleum and Asphaltum in California.

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GENESIS OF PETROLEUM AND ASPHALTUM IN CALIFORNIA.

By A. S. COOPER, State Mineralogist.

It can be tentatively stated that fossil bitumens are principally derived from terrestrial and marine vegetation, deposited in sedimentary strata, then changed to carbonaceous matter, and afterwards distilled by the heat of metamorphism.

In other words, the bitumens are Nature's coal oils and tars distilled in Nature's still, generally with infinite slowness when compared with a modern tar still or retort.

Although some of the hydrocarbons can be produced synthetically in the laboratory, still it is to be believed that nearly all, if not all, of the accumulations of fossil hydrocarbons owe their existence to the vital principle that they are derived directly or indirectly from organized beings—animal or vegetable, probably the latter, for reasons given hereafter.

In the decomposition of vegetable tissue, when air is wholly or partially excluded from it, as, for example, when buried in the ground, the constituent elements of the vegetable tissue re-arrange themselves mutually into new products, either with or without the co-operation of the elements of water, the oxygen gradually uniting with the carbon to form carbonic acid, which separates and leaves as a residue substances rich in carbon and hydrogen. It is in this way that bituminous coal, peat, and brown coal (lignite) have been formed from vegetable matter.

With carbonaceous material in the same deposit, the same series of strata, or in the same stratum, there are differences of composition. The varieties of carbonaceous materials may have been produced from different kinds of plant form, from which coal has been derived, and the peculiar conditions of the districts where the plants flourished before their downfall and inhumation or submersion. The changes that have taken place

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in the original plants, during their passage from woody fiber into coal, are ascribed to evolution of a part of their hydrogen and oxygen, as there are less of these elements in coal than in wood. This will be observed by viewing the following table:

Organic.	Formation.	C.	H.	O.
Wood	Recent	52.65	5.25	42.10
Peat	Recent	60.44	5.96	33.60
Lignite	Cretaceous and Tertiary	66.96	5.27	27.76
Brown Coal	Cretaceous and Tertiary	74.20	5.89	19.90
Coal	Secondary	76.18	5.64	18.07
Coal	Older	90.50	5.05	4.40
Anthracite	Crystalline	92.85	3.96	3.19
Graphite	Crystalline and Archæan	100.00	----	----

There is no strict line of demarcation between the above-named organic matter; the one below gradually merges into the one above.

The older the formation, the greater the amount of carbon contained in the coal, the amount of hydrogen and oxygen having been diminished. This fact may be ascribed chiefly or in part to the degree of heat and pressure to which the lower and older coal strata have been, and still are, subjected.

Graphitic and anthracitic varieties of coal are metamorphic coal produced by heat, the volatile matter being vaporized, which, probably, afterwards condensed in fissures and porous rock above, as bitumen, petroleum, etc.

Graphite occurs in the Archæan, but none of the other coals are found in these rocks; neither is bitumen or petroleum oil found in the Archæan formation, but they are found in all the other formations lying above the Archæan. From this it would seem that the bitumens originated in or above the Laurentian rocks, and not below them. The absence of the bitumens and petroleums in the Archæan formation is evidence against the theory that petroleums are produced by the action of water upon red-hot carbonized iron in the interior of the earth. It is at least conclusive evidence that this process is not at present in operation.

Graphite is, in all probability, the ultimate stage in the series of changes which vegetable matter undergoes, passing through the conditions of heat, lignite, and mineral coal, to end in graphite. Several modifications of graphite may be produced artificially. When cast-iron is melted with an excess of charcoal, it dissolves a portion of the carbon. This carbon, when

the iron is allowed to cool, slowly crystallizes out in the form of large and beautiful leaflets of graphite.

Anthracitic varieties of coal are associated with folded and metamorphic rocks. Anthracitic condition of coal may sometimes be traced to local effect of igneous rocks. As rocks grow less and less metamorphic, the more bituminous is the coal contained in them.

Graphite is disseminated in strings, veins, and beds through hundreds of feet of the lower Laurentian strata, and its amount is calculated to be equal in quantity to the coal seams of an equal area of the carboniferous rocks.

In Central Scotland, where the coal fields have been so abundantly pierced by igneous masses, petroleum and asphaltum are of frequent occurrence, sometimes in chinks and veins of sandstone and other sedimentary strata, sometimes in the cavities of the igneous rocks themselves. In West Lothian, intrusive sheets, traversing a group of strata containing seams of coal and oil shale, have a distinct bituminous odor when freshly broken, and little globules of petroleum may be detected in their cavities. In the same district, the joints and fissures of a massive sandstone are filled with solid, brown asphalt, which the quarry-men manufacture into candles.

Graphite has probably the same vegetable origin as mineral coal. It is now generally conceded to be of organic origin, the result of metamorphism of some of the products of destructive distillation of vegetable tissues. In general arrangement and microscopic structure, the layers of graphite correspond frequently with coal and some bituminous deposits.

The majority of coal mines in California are in the cretaceous rocks and the lower tertiary. The rocks underlying the tertiary formation and in the lower parts of the tertiary formation are in many instances metamorphic, the cretaceous and tertiary rocks having been changed to metamorphic rock by hydrothermal action, and, if they contained carbonaceous material, petroleum was distilled, which ascended in a vaporous condition and was condensed in the unaltered rocks. After condensation, it was carried upwards by gas and hydrostatic pressure, and, in some instances, by rock pressure.

The presence of nitrogen in the California petroleum oils has been adduced as a proof that they are of animal origin; this proof is not conclusive, as most all of the coals and carbon-

aceous shales yield nitrogenous products when subjected to destructive distillation. As a proof of the animal origin of petroleum, it has been stated that pools of petroleum have been found which were filled with live maggots.

Many hundreds of pools of petroleum in California have been examined without discovering any maggots or other forms of life in them, although there have been swarms of flies and other insect life in their neighborhood. In the vicinity of pools of petroleum, flies quickly discover and lay their eggs on spoiled or moist foodstuffs, meat, decaying meat, meat broths, dead animals, in manure heaps, etc. Taking into consideration the persistency of flies to deposit their eggs upon anything capable of sustaining the life of their young, it is to be believed that all pools of petroleum would be filled with maggots if flies were present and petroleum was a suitable food for their larvæ.

Maggots feed upon animal and vegetable tissues and liquids, and not upon their fats and oils.

When animal hydrocarbons are deprived of all animal tissues and liquids, they are not molested by flies. Petroleum is also found to be an excellent maggot-killer.

There are only four ways of preserving animal remains from decay and putrefaction: first, in a case from which the air has been completely removed and excluded; second, by antiseptic agents; third, subjected to a heat exceeding 100° C.; fourth, subjected to a cold under 0° C.

To secure and preserve any quantity of animal remains by any of these four ways, cataclysms of nature must occur. Geology does not show that any large quantity of animals have been inhumed in the earth by cataclysms; even provided animals were buried in this manner, there is sufficient oxygen present to start decay, and, after this has commenced, putrefaction ensues.

It is also claimed that the decay of organic matter is not due simply to oxidation, but to the action of organisms, ferments, or enzymes, which attack the organic substances and decompose them into their original elements or into simpler compounds.

The ordinary rate at which sedimentary rocks are deposited is too slow to effect the inhumation of animal substances so that they will be excluded from the air and preserved.

But few animal remains are found incased in ice, and these

are not buried beneath the earth; there is no other way in which they can be preserved by cold.

There is no way in nature that animal remains can be maintained at a temperature of 100° C. from the time of their death until changed to bitumen.

Very seldom are animal remains preserved by antiseptics in nature, and, if so preserved, their aggregate amount is small. All the ways that can be employed to preserve animal substances are destructive to animal life. The presence of life and the conditions and way necessary for the preservation of animal substances cannot exist in the same place at the same time.

In order that petroleum oil may be derived from animal remains, it is first necessary that such remains be placed and preserved in a condition for such change.

In the present age, the inevitable end of animals after life is to furnish nutriment to the scavengers of the earth and sea, or their decomposition by putrefaction.

There is no reason why, in former ages, this was not the ultimate fate of animals.

The products of the decomposition of nitrogenized animal substances are as follows: The oxygen of the substance unites with the carbon to form carbonic acid, while the hydrogen divides itself between the nitrogen, the sulphur, and the phosphorus, and forms ammonia with sulphuretted and phosphoretted hydrogen.

The surroundings would indicate that the fossils in the petroliferous formations of California lived and died, and were embedded in the same manner as the mollusca of the present day; in fact, a large number of the fossils in these formations are the prototypes of existing mollusca, and must have lived and died in the same manner. There is nothing showing that after death the mollusca existing at the present day are preserved for the future manufacture of petroleum. This is also true of the infusoria.

The fossil animals do not show any stage of transition between animal matter and petroleum oil.

Large quantities of fossil shells exist in the shales and sandstones of California; these are usually filled with silt, or the shells have been changed to silica, and the interior filled with silica, or molds and casts exist, the carbonate of lime having

been leached away. They only contain bitumen when the interspaces and cracks in the adjoining rocks are filled with bitumen. There is no carbon in these fossils, except in some instances the carbonate of lime constituting their shells. There is no carbonaceous matter from which bitumens could be derived by any known process. There are no more fossils in the rocks which are impregnated with bitumen than in those which are destitute of bitumen.

Bitumens are found in the unaltered sedimentary rocks of California sandstones, shales, limestones, etc. There is no bitumen in the metamorphic rocks. The only substances originally contained in these rocks, that could and can be converted into bitumen, are organic vegetable remains in the form of coal, lignite, and carbonaceous shales. These carbonaceous substances are not changed to bituminous unless distilled by heat.

Most all of the known beds of coal, lignite, and carbonaceous shale belong to the cretaceous or tertiary formation.

If bitumens exist in them at all, the surrounding and accompanying phenomena show that these accumulations of bitumen are secondary.

A primary deposit of petroleum is in the rocks in which it was formed.

A secondary deposit is where it has migrated from the rocks in which it was formed and accumulated in other rocks.

If petroleum is produced by destructive distillation, it cannot remain in the rocks in which it is formed.

The petroleum of California is not confined to any particular geological horizon in the Coast Range, but may exist in any of the sedimentary rocks lying above the altered rocks; therefore, palæontology is of but little value in determining its location.

The chief guide to the discovery of bituminous accumulations is the character of the rocks constituting the formation, and their structure and position.

There is no evidence tending to show that these accumulations or deposits are primary; and, if secondary, they may occur in any porous or seamed sedimentary strata of any age lying above the altered rocks.

The age of a formation may assist in the discovery of primary mineral deposits; but migratory fluids and gases will

circulate through any porous or seamed strata, and accumulate in such places as are rendered suitable through structure and position, irrespective of the age of the rocks.

The accumulations of bitumens in the domes and summits of the anticlines, and the existence of tar and gas springs, prove that they were, and are at the present time, migratory, and that the principal direction of their migrations was, and is, upwards.

In California, the upper cretaceous and the eocene, miocene, pliocene, and quaternary formations, when not metamorphosed or otherwise changed, consist of soft shales, sandstones, conglomerates, and limestone. The large majority of these rocks are soft shales and sandstones. The rocks of one age resemble those of another.

In California, the miocene seems to contain the largest amount of petroleum; this is owing to the fact that, in ascending from its place of origin below, it had not reached the pliocene in the same quantity as it did in the miocene; the pliocene, being the farthest away from the place of its origin and the eocene, does not have the same amount of exposures as the other formations, and, when visible, the formation is so broken, and tilted to such high angles, that the oil has escaped.

The fossil shells are vastly more numerous in the tertiary rocks of California than the remains of all other kinds of animals put together. Mollusca, similar to those of California, abound to an extraordinary degree in the tertiary in other places besides California, but usually they contain no petroleum.

In none of these ages are animal remains found in a state fit for the future manufacture of petroleum. Neither can there be found any substance that would suggest a state of transition between the fauna of these ages and bitumen.

But suppose, for argument's sake, that it is admitted that petroleum oil is derived from animal remains. There is no reason why the fauna of one of these ages should not be the origin of petroleum as well as the fauna of another of these ages. Oil which can be claimed as being indigenous is not found in the quaternary.

In California there are large areas of fine sand containing many fossil shells which contain no bitumen; if they had at

any time contained bitumen, there would still be some bitumen remaining in them, as there are many shells lying in such a position that the bitumen could not escape by draining from, or being floated out of them. If the petroleum originated in these shells, each shell would contain a modicum of oil, and would not be completely filled with petroleum or entirely destitute of the same, these being the conditions in which they are usually found.

If these fossil shells are full, these deposits must be partly or wholly a secondary one, as no mollusk could produce a quantity of oil equal to the size of its body; and if they were destitute of oil, it would tend to prove that they are not the source of oil.

It certainly cannot be claimed that animal remains in anticlines produce oil, while similar remains in the synclines are unproductive.

The presence of nitrogen in the bitumen does not prove that petroleum containing nitrogen is of animal origin, as nearly all plant remains contain nitrogen in greater or less quantity, and yield nitrogenous compounds by distillation.

How can the different kinds of bitumen be accounted for if they are derived from animal remains? Is the oil that originates from one species of mollusca different from that which is derived from another?

In Russia, the petroleum consists principally of the naphtene series; in Pennsylvania, of the paraffine series and a paraffine base; in California, of the olefine series with an asphalt base.

Adjoining fossil shells, when bituminized, contain similar bitumens; for instance, if one shell is found inclosing a bitumen containing six per cent of sulphur, the adjoining shells all contain bitumen containing six per cent of sulphur. This large amount of sulphur was not originally present in the body of the mollusca, consequently it must have been derived from some other source, and if derived from some extraneous source, the percentage of sulphur in the bitumen in each shell would not have been so constant—some would contain more sulphur than the other. This would lead to the belief that the bitumen was sulphurized before entering the shells, and is, therefore, a secondary deposit.

Then there are varieties of asphaltites, uinteite, albertite, grahamite, and elaterite.

It does not seem possible that the bodies of the mollusca, which so closely resemble each other in composition, should produce so many dissimilar bitumens.

When petroleum is found in fossil shells, it is also found in the porous or seamed strata in which the shells are embedded.

The character of the bitumen in the shells is the same as that which is in the porous strata, excepting that it is sometimes in a more liquid condition, owing to the fact that a greater opportunity is offered for the evaporation of the bitumen in porous strata than in closed shells.

Owing to the buoyancy of the bitumens in fresh or mineral water, their migrations are usually upwards until checked by impervious strata, or until they have reached the highest point to which water will float them, or until they reach the surface of the earth.

Very seldom do they descend, and then descent only occurs when the strata to which they have ascended are uplifted above permanent water by orogenic movements. They may migrate for a thousand feet, and, as stated above, generally upwards.

In the Ojai Valley is an accumulation of asphalt, lying like a huge black tear upon a hillside, which has slowly issued from the small springs at its upper end. Scattered throughout the Coast Range are similar deposits.

Distillation.—The maximum quantity of liquid hydrocarbons is obtained from the solids by a process of distillation under high pressure and low temperature, combined with rapid condensation.

Temperature and pressure exercise a considerable influence on the nature of the products of distillation. The method of cooling also exercises great influence in the re-arranging of the moleculés and upon the nature of the product of distillation.

Slow cooling or quick cooling makes no difference on some substances, but the difference between slow and rapid cooling has a marked effect on others.

If we reduce the heat of water from a high to a low temperature, it will not affect the constitution of the water; whether we lower the temperature slowly or quickly, the result will be the same. Water that is slowly cooled from the boiling

they are decomposed to hydrogen and carbon. The liberated hydrogen combines with the sulphur vapors, forming sulphuretted hydrogen.

Shales containing $\frac{5}{10}$ per cent of sulphur yield scarcely any paraffine on distillation.

YIELD OF GAS, OIL, ETC., FROM SHALES AND COALS AT HIGH AND LOW HEAT.

		GOOD SHALES.		BOGHEAD COAL.		GAS COAL.	
		High.	Low.	High.	Low.	High.	Low.
Volatile	Gas	13.65	2.54	37.32	4.83	20.49	6.49
	Am'onia water	3.65	6.47	2.43	3.23	3.09	7.24
	Tar or oil	11.04	17.65	20.65	50.29	17.08	26.45
	Sulphur	.99	--------	.18	--------	.29	--------
	Water at 212° F.	2.82	--------	.80	--------	4.15	--------
		32.15	26.66	61.38	58.35	45.10	40.18
Coke	Fixed carbons	4.16	10.81	9.01	12.40	45.00	49.93
	Sulphur	1.05	--------	.06	--------	.34	--------
	Ash	62.64	62.53	29.55	29.25	9.56	9.89
		100.00	100.00	100.00	100.00	100.00	100.00

What is known under the general name of petroleum includes a series of hydrocarbon oils varying widely in physical properties. Some are limpid fluids with many intermediate grades; others are found viscid and tar-like.

Hydrocarbons generally exist in three different conditions: first, the gaseous condition, wherein the equivalents of hydrogen are equal to, or greater than, the number of equivalents of carbon; second, in the liquid state, where the equivalents of carbon exceed the equivalents of hydrogen; third, in the solid state, where the carbon exceeds the hydrogen in still greater ratio than in the liquid state.

Their color by transmitted light ranges from a light yellow through orange and red to a reddish brown, so dense as to be translucent only in thin films; while by reflected light it passes from a light dusky color to a dark green and to a black. They differ as markedly in odor, and also in other properties, some having a very disagreeable smell, while others are considered even pleasant.

There is a wide range in their gravity. The greater the quantity of carbon in proportion to the hydrogen any one of them contains, the greater is its specific gravity, and the higher

its boiling point and density of vapor. In the same oil field, in the same series of strata, and in the same stratum there are differences of composition.

The following are the commercial names of the products of distillation of crude petroleum: cymogene, rigolene, gasoline, naphtha, benzine, kerosene, maltha, and paraffine. There is no well-marked division line between any of the above named products, but they gradually merge one into the other.

Their division is simply one of caprice. These hydrocarbons are extremely complex and different in composition. The proportion of carbon and hydrogen is extremely variable. There seems to be no end to the different combinations of hydrogen and carbon.

The great diversity in the physical and chemical conditions of the bitumen can be attributed: first, to the organic remains from which it was distilled—different kinds of terrestrial vegetation and marine vegetation—by natural process these organic remains may have been changed into peat, lignite, or coal before distillation; second, to the degree of temperature to which organic remains are subjected during distillation; third, to the pressure to which it is subjected during distillation; fourth, to the time consumed in effecting distillation; fifth, to the presence of different substances during distillation—sulphur, lime, water, oxygen, nitrogen, etc., which render their properties very different; sixth, to the condensation of the bitumen after distillation, whether rapid or slow, agitated or quiescent; seventh, to the material of the still; eighth, to repeated distillations; ninth, to evaporation; tenth, to sulphuration, oxygenation, etc. Electricity may also play an important part.

Maltha, asphalt, jew pitch, mineral pitch, and brea are hydrocarbons which contain either sulphur, oxygen, or nitrogen. They may contain one or more or all three of these elements in varying proportions. They can be produced synthetically by sulphurizing, oxidizing, or nitrogenizing petroleum oils.

Oxygen, sulphur, or nitrogen, when chemically united with a hydrocarbon, such as some of the petroleum oils, produces a resin-like substance, to wit: asphaltum.

One of the solid asphaltums, when taken from the ground, is brown, owing to its porous condition, caused by the evaporation of the petrolene. It melts at 245° Fahr. When it is

melted, it becomes black or blackish green. Another asphaltum, when taken from the ground, is black in color, shaded with brown, or red and dark green when sulphur is present. When purified it assumes an indigo-blue reflection. It is opaque, scentless, tasteless, and fragile, breaking with a conchoidal fracture, which has a glassy brilliancy. By rubbing, it acquires a resinous electricity. Its specific gravity varies from 1.100 to 1.247. At ordinary temperature it is readily reduced to a powder. In a condition of extreme subdivision it takes a brownish tinge. It melts at about 105° to 108° C.

Immediately above its melting point asphaltum is volatile, and, if the temperature is carefully raised, it disengages in abundance white vapors which belong to oils, which become thicker in proportion as the operation is prolonged little by little; but slowly the volume of vapors diminishes, gas ceases to form, and a deposit of carbon, slightly bituminous, is reached, which is solid and has the appearance and often the hardness of jet. When subjected to quick distillation in passing on towards the dark red, it sets free at the same time a mixture of brown oils, sometimes sulphuretted hydrogen and sometimes ammonia, while the retort retains about one third of its weight of loosely compacted carbon. It is entirely insoluble in water; it gives up to absolute alcohol a small quantity of a yellow substance which exhales the odor, and has the appearance, of resin. Ether extracts from it a brownish-black substance called petrolene. The portion left by the alcohol and the ether is asphaltene.

The yellow substances, petrolene and asphaltene, do not exist in asphaltum in defined proportions. Sometimes the petrolene will represent two thirds or more of the asphaltum. On the other hand, asphaltene composes almost exclusively other asphaltums. The properties of the asphaltums vary according to different proportions of these three principles.

Yellow Resin.—Absolute alcohol dissolves yellow resin without dissolving petrolene or asphaltene; it is also readily soluble in the solvents of petrolene and asphaltene. It has the appearance of a resin. When the solution in alcohol of the yellow resin-like principle is treated with liquid ammonia, it produces an abundant white precipitate, while small globules of petrolene spring up from the bosom of the liquid and come floating in greenish-yellow lentils to the surface.

PETROLENE.—This is brownish black in colof and has a soft and glutinous consistency. It is insoluble in absolute [illegible] Ether, benzine, benzene, acetone, and the fat oils dissolve it and the yellow resin, but leave the asphaltene intact.

Petrolene is also soluble in the solvents of asphaltene. The specific gravity of petrolene at 21° C. is 0.891. It burns with a very sooty flame. It has but very little taste.

A highly concentrated solution of caustic soda or caustic potash, when hot, dissolves petrolene; if some diluted sulphuric acid is poured into the liquid, a brown gelatinous substance is precipitated.

A current of chlorine precipitates the petrolene from its solution in benzine or in turpentine in brown and viscous flakes. These precipitates contain chlorine, and do not give anything further to alcohol or ether.

Hydrochloric acid precipitates petrolene from its solution in benzine in thick flakes; sulphuric acid, in a solid and viscous deposit, which is transformed in time into a brownish red.

In making the experiment with sulphuric acid, the acid must be carefully and slowly added.

If asphaltum be kept at a temperature of about 250° C. by means of an oil bath, until it no longer loses by weight, the petrolene is evaporated from the asphaltene.

ASPHALTENE.—Heavy petroleum oil, carbolic acid, turpentine, chloroform, and bisulphide of carbon dissolve asphaltene without residue. It burns like resin, leaving coke. It is black, brilliant, and breaks with a conchoidal fracture. In the fire it only becomes soft near 300° C., and decomposes before completely melting. When torrified upon a platinum plate, it diffusès an odor of burned fat, afterwards of a sharp taste, which reveals an acid. It is solid, hard, and fragile. When pulverized, it presents a mass of purple color, oftener of a brownish red. It develops, by friction, resinous electricity. In some of the asphaltums, analysis has disclosed a large proportion of oxygen; in others, a large proportion of sulphur. A current of chlorine precipitates the asphaltene from its solution in petroleum oils and turpentine.

Asphaltene is not sensibly affected by caustic potash or caustic soda in a concentrated solution in water.

The Formation of Asphaltum by the Resinification of Petroleum Oils.—When petroleum oils are left for a long time in the presence of oxygen gas, or the atmosphere which contains oxygen, and in the light, they absorb oxygen; some carbonic acid is set free, water is formed, their odor becomes weakened, and they likewise become viscous while they assume a darker and darker color. When petroleum oil is heated in a current of oxygen, it undergoes a quick change and turns into petrolene.

If a current of sulphuretted hydrogen is conducted into boiling petroleum, a very mobile sulphurized liquid is distilled, having an unbearable odor of onions. If this treatment is repeated with the new compound, a second portion of the sulphuretted hydrogen comes to reinforce the former, and the odor of the liquid becomes that of garlic. When this sulphurized oil is evaporated, a resin is formed.

If petroleum oil is changed by the compression of sulphuretted hydrogen, and then the sulphuretted hydrogen be decomposed to sulphur and water, the oil will be sulphurized and resinified.

If petroleum oil is distilled in the presence of sulphur, the oils will be decomposed and sulphur compounds formed in the shape of a resin. Petroleum oil treated with nitrous gas absorbs it with a slight development of heat; the petroleum becomes thicker and is partly converted into resin.

All the petroleum upon which azotic acid is caused to act, furnishes yellow resins.

If petroleum is boiled in a concentrated solution of nitrate of potash or of soda, the nitrate converts the bitumen into resin, and the liquid becomes a brownish red.

Polymerism of Asphaltum.—By exposure to daylight, asphaltum polymerizes; that is, it acquires a higher molecular weight, retaining the same atomic proportions. The stronger the daylight the more rapid polymerization takes place. When polymerized, its molecule consists of two or more simple molecules united to form a complex molecule. It can be changed from a state of polymerization to its original or simple state by heat.

Polymerization is much more rapid and conspicuous with asphaltene than with petrolene; the part of asphaltum soluble in alcohol does not polymerize.

Polymerization is more rapid and greater in asphaltum

containing sulphur than in asphaltum containing oxygen. When polymerized, the physical properties of the asphaltum are changed; it has a greater specific gravity, it is harder and more brittle; but the most marked change is that of becoming insoluble, or, to speak more exactly, of being dissolved with greater difficulty in its solvents than when not polymerized.

Asphaltum, on account of this photochemical action, is used in photography.

If a moderately concentrated solution of asphaltum, in spirits of turpentine or chloroform, be placed in a transparent bottle and securely corked, and then exposed for some time to the light of the sun, resinous substances separate and gradually appear, which dissolve with greater difficulty in these solvents. If heated, they dissolve; the greater portion of these separated substances adheres firmly to the sides of the bottle; a smaller portion remains in suspension in the solution.

Colored resinous substances will form in the California petroleums of commerce, if exposed to light, in the manner described above.

Solutions of asphaltum, which are to be employed in photography, must be kept in the dark.

Asphaltum is employed in photography in the following manner: When the solution of asphaltum with turpentine or chloroform is spread over a plate, and left in a dark room until it becomes nearly dry, which will require a few days, and the plate exposed in a camera, or placed under an object in contact with it, the time necessary to make the print varies very much, and can only be ascertained by experiment. When printed, the development is effected by quickly flooding with spirits of turpentine, which will at once dissolve the asphaltum which has been protected from light, and partly dissolve that portion which has been exposed to the light. As soon as the subject is seen to be fully developed, a gentle stream of water from a tap is allowed to flow over it to wash off the turpentine. If all operations have been conducted rightly, a very delicate and perfect picture in asphaltum is the result.

Anticlines, synclines, monoclines, centroclines, and quaquaversals, and also faults, exert a great influence in the accumulations of gas, petroleum oil, and water. Especially is this true in California, where the dips and undulations along the strike of the anticline are exposed and well defined.

Although a description of the different inclinations and curvatures of strata would seem elemental, a thorough knowledge of the effect of these inclinations is necessary for an understanding of the laws governing the accumulations of bitumen in California. In the Eastern States the slopes of the domes frequently do not exceed twenty feet to a mile, whereas in California the strata stand at a very steep angle with the horizon, frequently being overturned.

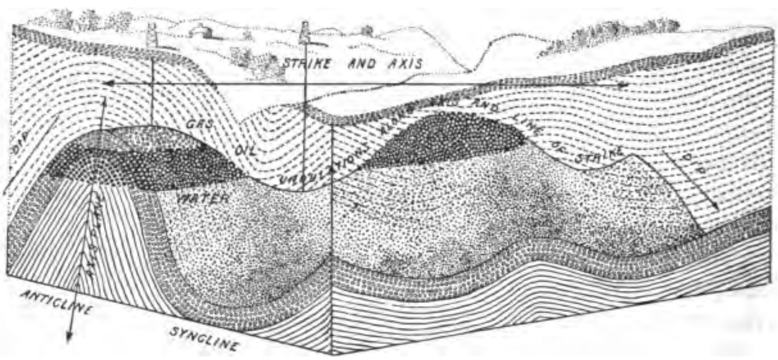


FIG. 1.—PLANO-SECTION SHOWING INCLINATIONS.

When a group of strata is bent into a curve like a saddle, with its convexity turned towards the earth, it is called an anticlinal curve. Such a condition of strata is shown in Fig. 1 above the word "anticline." A synclinal curve is exactly the opposite of an anticlinal curve. When the strata are folded or curved, so as to form a trough, the concave side of which is turned from the earth, this is called a synclinal curve. This is shown in Fig. 1 above the word "syncline." In both anticlines and synclines, the line in each bed, along which the change in the direction of the dip takes place, is called the anticlinal or synclinal axis of that bed, and the planes containing all the axes of an anticlinal ridge, or a synclinal trough, are called axis planes. The axis plane usually approaches verticality. Anticlines and synclines frequently nose out, or coalesce.

When an anticline undulates along the line of its axis, dome-like elevations occur, from the summits of which the beds dip away in every direction. In this case the strata are said to have a quaquaversal dip. An anticline is an elongated dome.

A quaquaversal, or dome, is a nest, usually of a great number, of different strata composing numerous overlying, gigantic, inverted funnels, the strata of the formation forming the sides of these rock funnels, all of which tend to guide and convey the ascending gas and oil to the apex of the dome.

When a syncline undulates along the line of its axis, basin-shaped depressions occur, towards the bottom of which the beds dip from all sides. This is called a centroclinal dip. A syncline is an elongated basin.

A fault, or dislocation, is a fissure or crack in the crust of the earth, accompanied by the elevation of the mass upon one side of the fault, while the other side remains stationary, or sinks down. Anticlines and synclines are often truncated by faults, and may be so faulted as to form the segments of a sphere or cone. If an oil-bearing bed, ascending to the north, be interrupted by an east and west fault, the further ascent of the oil northwards will be arrested, and then an abundant supply of oil may be obtained by boring on the south side of the fault; while for a considerable distance to the north, water will occupy the formation, to the exclusion of the oil. This is more apt to be the case where the throw of the fault is sufficient so that the edges of the porous strata are covered by impervious strata. Selvage frequently occupies the line of faults, generally caused by the movement of the two sides of the fault on each other, which have ground up the materials of the rock, forming a sheet of matter impervious to the flow of oil or water, or the faults may be filled up with mineral matter of various kinds, which are also impervious to oil or water.

When a formation contains permanent water, the accumulation of petroleum oil will be found near the upper part of the dome, as is shown in the plano-section, Fig. 1. The oil floats on the surface of the water, and if natural gas is present, it will be found above the oil. These three substances arrange themselves according to their specific gravity, the lightest on top.

Fig. 2 (see page 22) is a view of an anticline. The camera was pointed in the direction of its strike. The black line represents the plane of bedding, which was once horizontal, but is now curved in the form of an arch.

The unaltered rocks of California cover an area of forty thousand square miles.

Red Shales as Connected with the Genesis of Bitumen in California.—Shales were, and are, deposited in still and salt water. The iron contained in these waters and organic remains, both animal and vegetable, and other materials constituting the shales, were deposited contemporaneously.

If the iron was the peroxide of iron, ferric oxide (Fe_2O_3), by contact with organic remains, it was deoxidized and reduced to a protoxide, ferrous oxide (FeO), by the absorption of one equivalent of its oxygen; when the peroxide was reduced to a protoxide, carbonic acid, produced by the decomposition of organic matter, then united with the protoxide, forming carbonate of iron ($FeCO_2$).

The carbonate of iron imparts a bluish or greenish color to the deposit.

The accumulation of iron, in the presence of an excess of organic matter, retains the form of ferrous carbonate. In all coal measures, of all periods, whether carboniferous, jurassic, cretaceous, or tertiary, or in all cases where there is organic matter in excess in a state of change—in all strata, whether older or newer, in which there is organic matter in excess in a state of change (not graphite)—the iron is in the form of carbonate protoxide, or ferrous carbonate ($FeCO_3$).

Sulphide of iron, ferric sulphide (FeS_2), is subsequently formed and deposited instead of carbonate of iron. The sulphates of lime ($CaOSO_3$) and magnesia ($MgOSO_2+7HO$), and other sulphates which exist in sea water, when subjected to the action of decaying organic matter, out of contact with air, are deoxidized and converted into solubles, from which sulphuretted hydrogen gas is set free by the carbonic acid gas produced by the decomposition of organic matter. Sulphuretted hydrogen converts the soluble compounds of iron into sulphide of iron. The color of pyrites is brass yellow.

The presence of protoxide of iron, and of iron pyrites, in these shale beds, arises from the considerable amount of organic substances exercising a reducing action. The water flowing from the mountain heights, where there are no organic substances, exercises at first an oxidizing influence, by virtue of which the rocks over which it flows are decomposed.

The suspended substances carried down by these rivers, and the detritus swept along their beds, come, after a time, in contact with organic substances, by means of which the per-

oxidized iron compounds are again reduced. Consequently, the iron thus carried into the sea is, for the most part, in the state of protoxide, either combined with silica or with carbonic acid, the silicate being suspended, and the carbonate dissolved in the water.

When unaltered by oxidation, the carbonate of iron, with varying amounts of lime, clay, or sand, is dark grayish-blue or green, or even white, in color.

When unaltered by oxidation, the sulphide of iron is brassy yellow in color.

From the preceding explanation, it is safe to say that, at the time of their deposition, the carbonaceous shales were not red; and as long as they are not submitted to oxidizing influences, they will not become red.

When carbonate of iron is exposed to the oxidation of the air, it forms limonite (hydrous ferric oxide), which is usually of a brownish yellow, or brownish red color. These iron ores are found in all stages of transformation. On the outcrop, they are limonite; under dense cover, carbonate. While going from the outcrop inward, the limonite constantly decreases in proportion to the carbonate. In the alteration of the compact carbonate, the line of chemical change and color is usually very sharply defined, and the limonite covering can often be entirely removed from the inclosed core of carbonate by a blow with a hammer, the limonite covering preventing the carbonate core from being oxidized by the air. In shales charged with gray carbonates of iron, the following reaction takes place by the action of the air: the carbonic acid is released, and part of its oxygen oxidizes the iron.

Gray shales containing finely divided pyrites, or bisulphide of iron, are converted by heat into bright red, the sulphur being released, leaving the shales charged with red oxide.

The color of burnt ferruginous shale is entirely due to the amount of iron present. Gray shales containing less than one per cent, or one and one half per cent of iron, change by heat to various shades of cream color, or buff; while those containing two per cent to ten per cent, or twelve per cent of iron, produce, by heat, pink and bright red bodies. The depth of the color depends merely on the amount of iron present, the buff shades gradating into the deeper shades of red.

A group of stratified rocks usually consists of various species,

arranged in alternating beds, a series of beds of many hundreds, or even thousands, of feet in thickness, containing strata of shale, limestone, or sandstone.

Some strata are seamed or porous, and easily penetrated by fluids, serving as conduits and reservoirs for fluids. Some strata are nearly impervious to fluids, while others are practically so, frequently serving as incasements for the conduits and reservoirs formed in, and by, porous and seamed strata.

All stratified beds have been originally deposited in a horizontal position, or approximately so. While these beds were in the horizontality of their deposition, and incased by impervious strata, there was little or no circulation of fluids within their porous or seamed strata. When they were tilted and inclined to the horizon, at angles varying from the horizontal to nearly absolute perpendicularity, and their porous and seamed strata exposed to the entrance of fluids, by denudation, fracture, or otherwise, and an exit for the fluids was supplied, or produced, at a lower level than the place of its entrance, the circulation of fluids commenced, slowly at first, gradually increasing as the inclination and exposure of the different strata became greater. The course of the circulating fluids was complex and anfractuous.

Water, supplied by the rainfall of the region, enters at the outcrop of the porous and seamed strata. If the porous and seamed strata are incased in impervious strata, the greater the depth to which the strata extend from the place of entrance of the water, the greater the pressure will become. In some instances this pressure will be very great, forcing the water into comparatively impenetrable rocks.

The water, percolating and circulating through the porous and seamed strata, by its solvent action, accumulates mineral ingredients. These waters, saturated with minerals, coming in contact with other minerals existing in the shales, by chemical reaction produce heat. This heat contracts and fractures the shales, permitting a freer circulation of water.

This chemical heat distills petroleum from carbonaceous shales, and oxidizes the carbonate and sulphide of iron, producing the red colors of the shales, and water of different temperatures, charged with mineral ingredients, will frequently rise, by hydrostatic pressure, through fissures and faults, etc., to the

surface of the earth, forming mineral springs. These springs are often accompanied by bitumen.

But very few fossils exist in these red pyrogenous shales, as they have been obliterated by the solvent action of hot water, or by the chemicals held in solution by the circulating waters; or, if the molds or casts of their external forms existed, they have disappeared from the same causes, or they have been crushed and distorted beyond recognition.

Red Shales in California.—Red shales in California are the effects of chemical heat. Strata which have been more or less altered by the action of heat emanating in the strata from chemical reaction, consist of burnt shale, porcelain jasper, earth clinkers, slag, and white shale.

Burnt Shale.—Its color is usually red, sometimes gray, yellow, or brown, and gradating from cream color to brilliant red. It is clay, or shale burnt, but not so much changed as to form a porcelaneous mass.

Porcelain Jasper.—It is shale, or changed into a kind of porcelain by the action of heat. It is dark red, yellow, or striped yellow and red.

Earth Clinker or Slag.—This is a shale, converted into a kind of clinker slag. It is black brownish or reddish, and it has occasionally a tempered steel tarnish.

Sometimes it shows iridescent colors. It is vesicular, usually amorphous, but occasionally possessing the prismatic form of artificial coke.

White Shale.—During these chemical fires, carbonic acid, sulphuretted hydrogen, and aqueous vapors are formed; these exhalations, in passing through the shale, bleach and decompose it. The silicates are decomposed by the continuous action of aqueous vapors, at 212° Fahr., sulphuretted hydrogen, air, and the alkalies, magnesia and lime, are nearly removed, and metallic oxides are carried away. The vapors convert the shale into a white clay, or nearly white, when a small quantity of iron still remains. By the removal of the alkalies (magnesia and lime) and metallic oxides, the quantity of alumina and silica increases. The absence of the bases, such as lime and iron, in these bleached shales, gives growth to a different

vegetation from that which grows where these bases exist. This difference in vegetation is a good index to deposits of petroleum and bitumen. The removal of these substances makes the shale incapable of sustaining vegetable life; the absence of, or scarcity of, vegetation is indicative of this action. Immense beds of these white and altered shales frequently occur in the vicinity of bituminous deposits, generally running in the direction of the anticlines.

Not infrequently the marine shales, through which hot silicated waters have percolated, and from which the bases, such as lime, magnesia, iron, etc., have been carried away by the solvent action of these waters, contain diatoms in large numbers, whereas the adjoining shales, which have not been leached, do not contain diatoms in any notable quantities.

Diatoms abound in the hot springs of California and Yellowstone Park. In the hot springs of the Yellowstone Park, deposits of this kind are now forming over many square miles, and are five or six feet thick.

Why should they not originate and abound in percolating hot silicated saline waters, and be deposited in the interspaces and joints of the shales through which the water percolates ?

Isolated bodies of diatomaceous earth in California would indicate that they originated and were deposited from springs.

At the Buena Vista Oil Springs, in Kern County, quaternary deposits of infusorial earth exist, the stratification of which is horizontal; it has either been denuded from the leached and adjoining formation, and deposited in still water, or else it originated in quaternary waters, and then deposited; probably the latter is the case, as these strata do not show the presence of other material from the adjoining formation.

From the immense amount of mineral matter which has been carried away by the solvent action of water—thousands of tons of fossil shells, silica, magnesia, iron, etc.—and the large area now occupied by the whitened shales, the flow of mineral water, at some former time, must have been very copious as compared to the flow at the present time.

The illustration (Fig. 3) shows an outcrop of red shales and porcelanite near Mount Solomon, Santa Barbara County.

Phenomena Attending Red Shales.—The red shales are discovered by their bright colors, by the heat of the earth in

their vicinity, and sometimes by smoke. Sulphurous and other vapors frequently occur. These vapors, in their course upward, are condensed, and incrust the fissures of the rocks, and even the surface of the ground.

Mineral springs, hot and cold, issue from the ground in their vicinity. The earth is charged with salts and minerals

FIG. 3.—OUTCROP OF RED SHALES AND PORCELANITE.

occasioned by the percolation and evaporation of these mineral waters. Shales, through the joints of which these mineral waters have flowed, have become impregnated with salts, and the salts, subsequent to the flow, have become vitrified by heat.

They are further known by the issuance of warm or cold natural hydrocarbon gas, by seepages of bitumen in their

neighborhood, by fissures, joints, and porous rock filled with asphalt, and by the almost total absence of fossils in the burnt shale porcelanite and clinkers, which have been obliterated by hot water and heat. Before chemical heat commenced, these shales did not contain over two per cent of carbonaceous matter—not sufficient for them to be set on fire at the surface.

PHYSICAL CHARACTERISTICS.—When unburnt, these shales are easily split along their lines of lamination, but when burnt to a tile red, or to a greater degree, their fissility is partly destroyed. When unburnt, their lines of lamination are plainly visible; but when burnt, their lines of lamination are obscured or obliterated. When unburnt, they have a clayey-like smell when breathed upon; but this physical characteristic is partly, if not altogether, lost when they are burnt. When unburnt and suspended so as to freely vibrate, they have a dull sound when struck; but when burnt, they become resonant. In this characteristic they resemble brick. Chemical fires destroy, or partly destroy, their lines of lamination, their fissility, and their argillaceous smell when breathed upon, but increase their resonance. These characteristics do not occur when these shales are discolored by the oxidation of the iron naturally contained in them, through the agency of water without heat. Serpentine cups filled with a pigment made from these bright shales are dug from the graves of the aborigines.

About thirteen miles east of Santa Barbara City, an excavation was made on the bluff of the ocean for the road-bed of the Southern Pacific Railroad, and the gray shale, charged with chemical substances and carbonaceous matter, taken from the excavation, was thrown over the bluff, forming a conical-shaped pile, composed of pieces of shale containing from one to eight cubic inches. Water could easily penetrate the broken shale, and air could easily circulate through the mass. When the winter rains fell upon this pile, chemical action commenced, producing sufficient heat to vitrify and weld the pieces of shale together. A large part of this shale was burned to a red porcelanite, and the remainder was colored a buff shade, gradating into the deeper shades of red. Above the railroad track, the face of the shale bluff has been cut off to the angle of repose by the railroad company. This smooth surface is a good place to observe the action of chemical heat and attending phenomena.

La Patera Mine.—La Patera Mine lies nine miles west of the City of Santa Barbara. Its relation with a lake and the ocean is shown in Fig. 4. The lake contains about sixty acres. Along the periphery of the lake, the stratification of the shale dips towards the lake at an angle varying from 30° to 40°. The composition and the arrangement of the component parts of the soil are the same upon the island as upon the mainland. The shale must have existed at a level shown by the dotted lines in Fig. 4, and subsided after the deposition of the soil, otherwise the soil would not have been deposited upon the island in a manner similar to that of the mainland. This subsidence was probably occasioned by the contraction of the underlying shale,

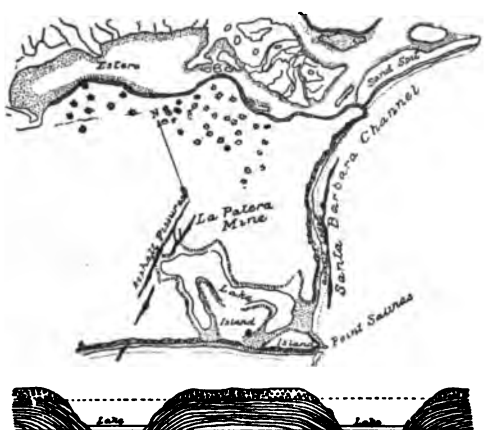


Fig. 4.—La Patera Mine, Santa Barbara, California.

produced by chemical heat. Some idea of the contraction of the shale by burning may be learned from the contraction of brick through burning. Before burning and when in a dry condition, a brick is 8 inches long; when burned—not vitrified—it is 7⅞ inches long, and when vitrified it is 7¾ inches long.

If the basin of the lake near the La Patera Mine had been formed by erosion of the land by sea or surface water, the shale would have been squarely cut off and not contorted so as to dip towards the lake. In the excavation at the mine at the depth of 100 feet, a temperature of 105° Fahr. is generated in the shales by chemical heat. Circumjacent to the lake are fissures filled with hard asphalt, through which comminuted shale and mineral water are disseminated.

Off the shore, petroleum rises from submarine springs, covering a large surface of the ocean with a thin film of iridescent oil, the odor of which can be detected at a long distance. Ledges of hard asphalt exist in the ocean, below high tide, which run nearly parallel with the shore. Surface wells show the existence of water highly charged with mineral substances, in which petroleum is discovered. So far, no potable water has been found near this mine.

Six miles west of Santa Barbara, on the Calera Rancho, and on the ocean shore, an area of twenty acres has subsided some

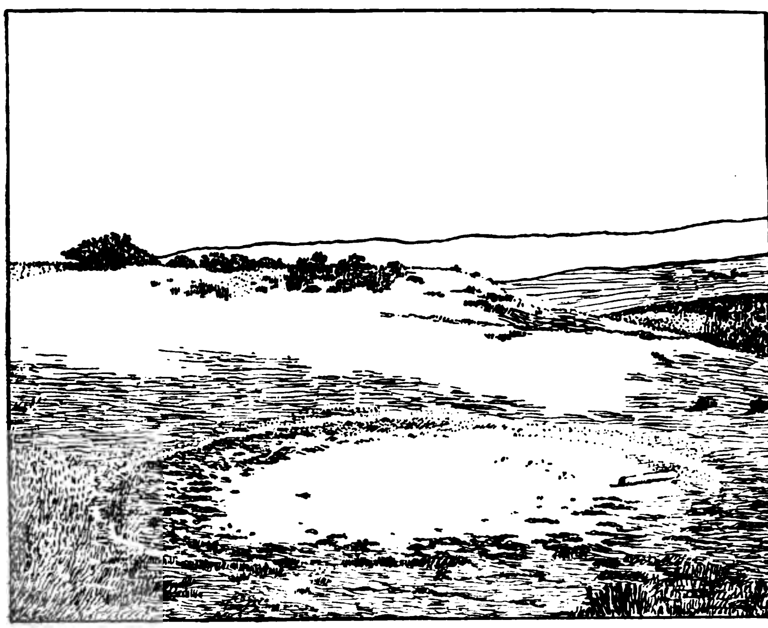


FIG. 5.—LAKE FORMED BY SUBSIDENCE OF LAND.

twenty-five feet; of this subsidence, four feet occurred in five years. This subsidence has occurred through the contraction of the shale. The surface of the subsidence is rifted and seamed, and from these rifts and seams sulphurous and other vapors ascend. The ground is hot. The bluff is composed of burnt shales, showing tints from a cream color to a brilliant red. Water containing salt seeps from the base of the bluff. Shales with carbonaceous material, shales saturated with bitumen, and smoky-looking shales surround the hot places.

Near the hot places, heavy petroleum oils ooze through the shales. To the eastward and westward heavy and thick petroleum tars ascend through the cracks and seams and joints of the shale. Some of the seams of shales, containing a small proportion of bitumen, have hardened to such an extent that they resemble dark flint, and will cut glass.

Lyell gives the following: "Captain Mallett quotes Guinillar, as stating in his description of the Orinoco, that about seventy years ago a spot of land on the western coast of Trinidad, near half-way between the capital and an Indian village, sunk suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants." A similar subsidence at an earlier period may probably have given rise to the great Pitch Lake of Trinidad, the cavity having become gradually filled with asphalt. There are a number of places in California near these red shales from which natural gas issues. Some are hot, showing that they are formed at a high temperature.

Fig. 5 is a view of a small lake formed by the subsidence of the land near Mount Solomon, in Santa Barbara County.

It may not be out of place to mention in this connection the occurrences of red shale in other parts of the world in which bituminous deposits are known to exist.

Red Shales in the Island of Trinidad.—The formation of the island of Trinidad consists of clay, loose sands, shales, limestones, calcareous sandstones, indurated clays, porcelanites of brilliant red colors, with pitch deposits and lignite here and there.

The only substances containing sufficient carbon and hydrogen for the formation of asphalt, and likely to be inclosed in the strata, are vegetable remains. They are particularly abundant at La Brea, where most of the asphaltic beds have been originally carbonaceous and lignitic shales. Mineral springs abound throughout the island. In a series of loose sands, clay, and shale, lies Pitch Lake, seemingly occupying a depression in the strata. (See Fig. 6, page 34.) To the southward of the lake the shore is made up of bold cliffs, the strata of which consist of indurated clays. They also present thick veins of porcelain jasper. Strata of loosely coherent sandstone also abound, some of which are impregnated with bitumen. Rounded

pebbles of pitch and porcelain jasper form a beach at the foot of the cliffs. A species of coke is occasionally observed along the shore with a porous structure and the prismatic form of the artificial product, but, of course, much denser, on account of the large proportion of earth. Near the lake is a red, yellowish substance, semi-baked, evidencing that a considerable degree of heat attended its formation. Part of the impurities in the Trinidad asphalt consist of comminuted red clays or shales, with some sand.

It is evidently not adventitious at the surface, but must have been thoroughly incorporated, and brought up from the depths with the bitumen, judging from the constant amount, dissem-

FIG. 6—PITCH LAKE AT TRINIDAD, W. I.—From an old print.

ination, and character in all parts of the deposit. Water, containing all the mineral ingredients of strong thermal water, is found in the Trinidad asphalt. The presence of borates, iodides, and so many forms of sulphur compounds, and other characteristics, show that the water must be of the same origin as that of many thermal springs. This water, in all unaltered pitch, shows that the formation of the pitch and water must have been simultaneous, and cannot be considered adventitious.

It would be impossible for water, in any adventitious way, to become intimately mixed with the bitumen, so as to form, practically, an emulsion. Near the center of the lake is a body of pitch, softer, blacker, and newer than that of the

remainder of the lake. Gas constantly issues from the cracks in the bitumen. These phenomena show that asphalt is being distilled at the present time. The porcelanite and red shales must have been formed by heat created in the strata themselves, as these shales are burned uniformly, in no place showing a greater degree of heat than in another. They are, probably, formed in the same manner as similar rocks in California. The depression in which Pitch Lake lies, was, probably, made by the subsidence of the surface of the earth, caused by the heat contracting the underlying shale. There was no focus to this heat, no central point. If there was, in the material next to the central point the evidences of heat would be great, gradually decreasing as you went from the focus; this is not shown. To illustrate, bricks of very different qualities are to be found in the same kiln, for as the fire is applied below in arches, the lower bricks in their immediate vicinity will be burnt to great hardness, or, perhaps, vitrified; those in the middle will be well burned; and those on the top will be too little burned. Even then the bricks the farthest from the fire would not have been burned to this extent, if it were not for the numerous flues left between the bricks in the construction of the kiln. The intense heat of a furnace is confined by a footwall of firebrick. Three feet of lava will confine the heat of melted rock underneath. From the uniform burning of these shales, the heat must have originated in the shales themselves. A good, clean red heat is required for the burning of brick; it is fair to suppose that this temperature is required to produce red shales.

Porcelanites and vesicular clinkers are scattered throughout these red shales; they are not centralized. No fumaroles connect these porcelanites with a central fire. Moisture was concerned, as is evidenced by their even burning. Moisture was the vehicle of heat, as the burning would not have been so uniform in its effect if disseminated by conduction or radiation. The parts of the shale burned to porcelain resemble earthenware and stoneware; to burn earthenware and stoneware, a clean, white heat is required.

Arborescent forms, of huge scale, of these hydrothermal shales extend their ramifications throughout the earth in the vicinity of bituminous deposits. This form also goes to show that their burning was accomplished by chemical action, with

the presence of moisture, and not from radiation or conduction from a focalized fire. Nearly all readily solvent substances, and all volatile substances, have been removed from these red shales, or, where solvent substances now exist in them, they are different from those that were in them at the time of their formation. The noticeable bright red colors of these shales could not have been produced by the oxidation of the iron in the shales by water alone; heat must have been present to produce them. This heat would be sufficient to distill any carbonaceous substance contained in them.

In the metamorphic rocks of the San Rafael range of mountains of Santa Barbara County, it can be plainly seen that these porcelanized shales were converted into serpentine. All gradations from shale to serpentine can be found: shales reddened by heat, porcelaneous masses still retaining the structure of shales, and porcelain partly converted into serpentine. There are no visible signs of metamorphic action now in operation where the serpentine is exposed to view, but in the tertiary shales and sandstones to the west, especially in the hills lying north and south of the Los Alamos Valley, this metamorphic action is going on at the present time.

These red shales lie above and precede greater metamorphism, such as is exhibited by serpentine and quartzite, and, probably, metamorphic granite. This can be seen where erosion has been great enough to expose the contact between metamorphic rock and red and unaltered shales. When burnt, the cracks and seams in the shale are large, showing the extent to which they have contracted. Near the surface, the red shales are vesicular, and look as if they had faulted. These red shales are very much distorted and contorted; many of the contortions have a radius of but a few feet. No carbonaceous matter exists in these red shales. No bituminous substances exist in these red shales, unless they have entered subsequent to their burning. There is also an absence of sulphur. Carbonaceous and bituminous substances, and sulphur, are disseminated throughout the strata adjoining the red shales.

At the time of their deposition in sea water, and before any alteration had taken place, the red shales should contain chloride of calcium, carbonate of calcium, carbonate of iron, carbonate of magnesia, sulphate of calcium, etc., vegetable matter in a fine state of subdivision, and, in some places, large

deposits of vegetable matter; this organic matter, in time, becoming carbonaceous shales and seams of coal. When these shales are heated with a chemical heat, the following described vapors and gases are given off: sulphur dioxide, carbonic acid, sulphuretted hydrogen, carburetted hydrogen, distilled from the carbonaceous substances, nitrogen derived from the same source, etc. These vapors are forced into the circumjacent formation, which is highly charged with mineral matter originally present in the shale, and which had been deposited from hot water. Chemical actions arise when these vapors, or their condensations, come in contact with the minerals existing in the shales, causing heat. There remain in the shales, after the vapors and gases are eliminated by heat, oxide of calcium, oxide of iron, etc. Mineral waters and gases coming in contact with these substances produce heat. These chemical actions and reactions are complex and numerous. By these chemical actions and reactions, distillations and condensations, the alteration of the shale by heat becomes progressive and cyclic. This heat, under great pressure, and through subsidences and orogenic movements, is intensified. Chemical reactions are augmented through pressure and hydrothermal action. The hydrocarbons and other substances are distilled and condensed, dissociated and united, a multiplicity of times. Mineral springs, ranging in temperature from that of the earth, from which they issue, to the boiling point, are frequent in the neighborhood of these burnt shales. They contain, in notable quantities, sulphate of sodium, magnesium, and calcium, aluminum, carbonate of sodium, calcium, and magnesium, chloride of sodium, potassium, and calcium, silica, and, in excess, carbonic acid, sulphuretted hydrogen, carburetted hydrogen, and traces of arsenic, sulphuric acid, and iron. Besides the visible phenomena, the warmth of these springs shows that this metamorphic action is still in progress.

Deposits of bitumen, in California, are found in sedimentary rocks of all ages, and principally in three different ways: 1. In superficial detritus; 2. In veins; 3. In porous or seamed strata. The bitumen may be of any consistency—gaseous, fluid, viscous, or solid.

Bitumen often occurs in superficial detritus or alluvium. This character of deposit is usually the overflow of tar springs, into which the detritus from the surrounding country has

been washed or blown, and, where mineral tar is sufficiently liquid, it has percolated into the underlying earth. The detritus, when saturated with mineral tar, most always has been repeatedly burned, leaving black, vesicular clinkers, which are frequently refilled, where there has been a flow of tar after the fire.

Cooking utensils of the Indians are found in the vicinity of these tar springs, showing that they were used for purposes of fuel. After this they were set on fire by shepherds, so that the fleeces of their sheep would not be injured, or lambs suffocated by going into the sticky mass. Where the bituminized detritus has escaped the fires, and exists below the clinkers, it contains about five per cent of brown and friable bitumen, having a specific gravity less than that of water. It consists of seventy per cent of asphaltene and thirty per cent of petrolene. The accompanying map section and view show the Buena Vista Oil Spring, at Asphalto, Kern County, California. (Fig. 7.)

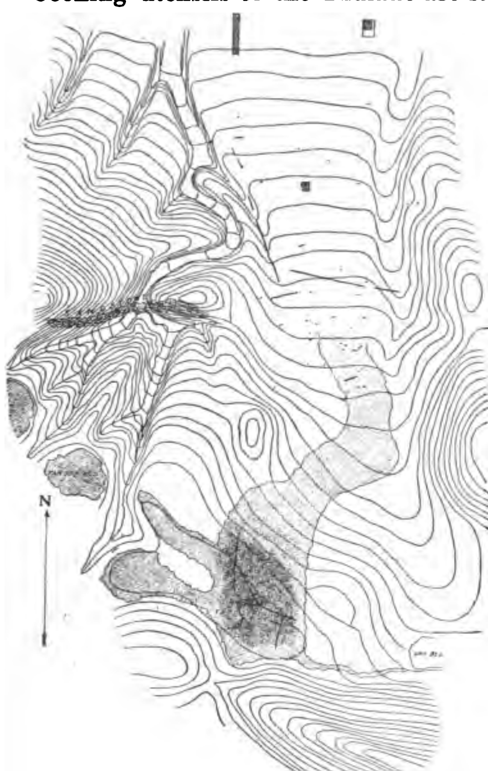


FIG. 7.—BUENA VISTA OIL SPRING, ASPHALTO, KERN COUNTY, CALIFORNIA.

The mineral tar reaches the surface at the place marked "tar spring." At the place marked "tar springs," a number of trenches have been cut, and a tank erected, so as to intercept and save the tar. These trenches are cut in clinkers and comminuted shale, which is often saturated with tar. Thin layers of detritus, impregnated with mineral tar, lying nearly

horizontal, are intercalated with thicker layers of detritus, which contain no bitumen. These beds are formed by flows from the tar springs and deposition of detritus denuded from the adjoining hills. Before this deposit was worked, mineral tar had flowed from the springs over the surface of the clinkers, until it had reached a thickness of from one to six inches; it had evaporated and oxidized, becoming stiff. It was of different degrees of purity, sometimes absolutely pure; at other times, it contained as high as eighty per cent of detritus. In 1891 and 1892 this concreted tar was being mined and refined. At the present time there are but a few tons, which are scattered over the ground, in small pieces. It has been estimated that, in recent years, these springs afforded about one hundred and sixty barrels annually. There are a large number of other tar springs in California, nearly all of which have been burned in the manner described above.

In the shaft sunk at the Hancock deposit, lying northwest of the City of Los Angeles, in the center of what appeared to be an old tar spring, on the surface were found the bones of domestic animals—horses, cattle, sheep, etc.; at a greater depth the bones of the bear, elk, and other wild animals; and, resting on the shale beneath the bituminized sand, at a depth of about thirty feet, were the bones of the *Elephas Americanus*. During the latter part of the summer season, in California, the natural grasses dry up, but, owing to the slight amount of water which ascends with the bitumen, as it does at the present time, many years ago, during the dry season, there grew, surrounding these asphalt springs, green and succulent herbage. This herbage was the bait of the trap which tempted these herbivorous animals to their death. With everything else dry, these green herbs were an irresistible temptation. In struggling to get to them, the animals became mired in the tar lake and suffocated, their bones gradually sinking to the bottom.

The *Elephas Americanus* seemed to be the first one that met this fate, as his bones rest upon the underlying shale, below the remainder of the fossils. These springs must be very old, as it is many years since the American elephant fed upon the plains adjacent to the spring.

Veins of asphaltum, being rents, seams, and fissures filled with asphaltum, occur, usually vertical, or not far from vertical. An innumerable number of small faults, contortions, and

shales are burning, large amounts of sulphur vapors are disengaged. It is reasonable to believe that these vapors sulphurized the bitumen in their neighborhood, forming asphaltum. Mineral waters, containing sulphuretted hydrogen in large quantities, usually accompany the ascent of the asphaltum. The earth adjoining the veins is usually charged with mineral matter, deposited from infiltrated mineral water. If these openings and sulphur vapors had not been made and generated, through the contraction and burning of the shales by chemical heat, the asphaltum would not have been formed, nor could it have reached the surface of the earth.

The physical characteristics of the asphaltum filling these veins are extremely variable. In consistency, it gradates from a hard rock to a viscous condition. The asphaltum contains, intimately mixed, from one per cent to seventy per cent of impurities. The impurities hardly ever exceed seventy-five per cent. The presence of more than seventy-five per cent of impurities makes the bitumen so stiff that it cannot be forced through the cracks and seams. In the vicinity of the injected veins there are beds of shales containing from ten per cent to fifteen per cent of bitumen, but existing rock pressure is unable to move them.

The impurity in some of these asphalts is infusorial earth, in others, sand, while in others, finely ground shales and angular fragments of shales and fossil shells, or all of these impurities may be present in the same deposit. Shale preponderates as an impurity; in fact, the impurities are derived from the rock which the asphaltum encountered during its ascent. Most of the time the impurities are very fine and light, making the refining of the asphalt, by any known process, difficult.

The thickness of these veins of asphaltum is variable; sometimes they are twenty feet in thickness, decreasing until they become the thickness of a knife blade. In exploring for asphalts, these small seams are followed, and often lead to thicker parts. The asphaltum breaks with a conchoidal fracture, some of these conchiform pieces being ten feet in diameter. The viscous asphaltum cannot enter the interstices or pores of the rocks of the formation; especially is this true where the pores or interstices of the rocks are filled with quarry water; consequently, when it is urged upward and forward by

rock, hydrostatic, or gas pressure, it exerts a pressure in all directions (similar in action to a hydraulic press), and through this pressure pushes the rocks asunder, making room for itself.

The pressure required is not great when the shale is contracted on one or both sides, the asphaltum being constantly alert to take advantage of any movement of the earth.

Next to these bituminous veins, the formation is of a bluish color, owing to the presence of a slight amount of bitumen. These veins entered the formation subsequent to its subsidence, as the veins are not faulted; although frequently very tortuous, they are continuous. These veins sometimes bisect the brown bituminized sand, showing that they were injected subsequent to the filling of these sands with bitumen, and even after they had become brown and indurated through long exposure. These veins of asphaltum frequently contain fossil shells and shark's teeth, which must have been brought up from lower strata, as no similar fossils occur in the adjoining walls of the vein. These fossil shells are filled with bitumen, mixed with the silt and sand that entered them when they died.

The bitumen in the shells must have been much more liquid when it entered them than at the present time. At the present time the bitumen is too stiff to enter the shells. Sometimes the bitumen in the shells is much softer than that in the veins, and sometimes it is of a yellow color. Slickensides, on both sides of these bituminous veins, show that the material has moved upwards. Fossil shells, embedded in the hanging wall of these veins, have plowed grooves in the asphaltum as it ascended. At the Waldorf Mine a groove was formed in this manner, ten feet in length.

These veins of asphaltum, in several instances, are found injected into the detritus which has descended from the adjoining hills. Tunnels and shafts, excavated in the formation containing these veins, have been partly filled with the ascending bitumen. At the La Patera Mine, in sinking upon some asphaltum, it was discovered that the excavation was being made in an old shaft, which, outside of the earth that had fallen into it, was filled with asphaltum. At a depth of fifteen feet, an old-fashioned pick and sledge-hammer were found, which must have been buried for a long number of years. Inquiries were made, but it could not be ascertained who sunk the shaft. At the La Patera, limpid sea water is inclosed in cavities in

the asphaltum, its limpidity showing that sea water has no effect upon the asphaltum. In the Santa Barbara Channel, below high-water mark, near the La Patera Mine, veins of this mineral occur. Owing to the plastic nature of this character of asphalt, and the broken condition of the formation in which it usually occurs, it is very difficult to mine. When inclines, tunnels, shafts, and other excavations are made in asphalt, or near it, they are hard to maintain, as the asphaltum lying above or near the excavations, even below them, commences to move through rock pressure, so that the excavations are soon destroyed.

Deposits near excavations give evidence of their existence by the earth bulging into the excavation. Wedges, picks, and other tools, used in mining the asphaltum, become sharp, instead of dulling.

When mined and relieved from pressure, occluded gas expands in the asphaltum, making it very vesicular.

In Fig. 9, A A portrays unaltered shale, greatly distorted by subsidence, caused by the contraction of the red shale, D D. B B B B, veins of asphaltum squeezed and forced up by rock pressure exerted by the shale A A, owing to their broken and contorted condition. C C, shales filled with condensed hydrocarbons, which were vaporized by hydrothermal heat in the red shales.

Near or adjoining the red shales, the shales are filled with liquid asphaltum; in some places the shales and the liquid asphaltum have formed a mud, which is forced outwards and upwards by the weight of the superincumbent shale, through cracks and seams, to the surface of the earth. Farther away from the periphery of the red shale, the shale has a smoky appearance, owing to the condensation of different vapors, generated by hydrothermal heat in the red shales, D D. D D, red shales which have contracted through the action of hydrothermal heat, such contraction causing subsidences in the overlying shales, A A—such subsidences opening fissures and cracks, B B B B, permitting the ascent of the bituminous mud, urged upwards by rock pressure, and, maybe, by gas and hydrostatic pressure. Underlying the red shales is serpentine, being shales metamorphosed to a greater extent than the red shales. Engraving Fig. 9 on the following page gives a view of a formation into which veins of asphaltum have been injected.

Reservoirs for oil and asphaltum are created as follows: The porosity of limestone is created by chemical action, the changing of limestone into dolomite; the porosity of sandstone,

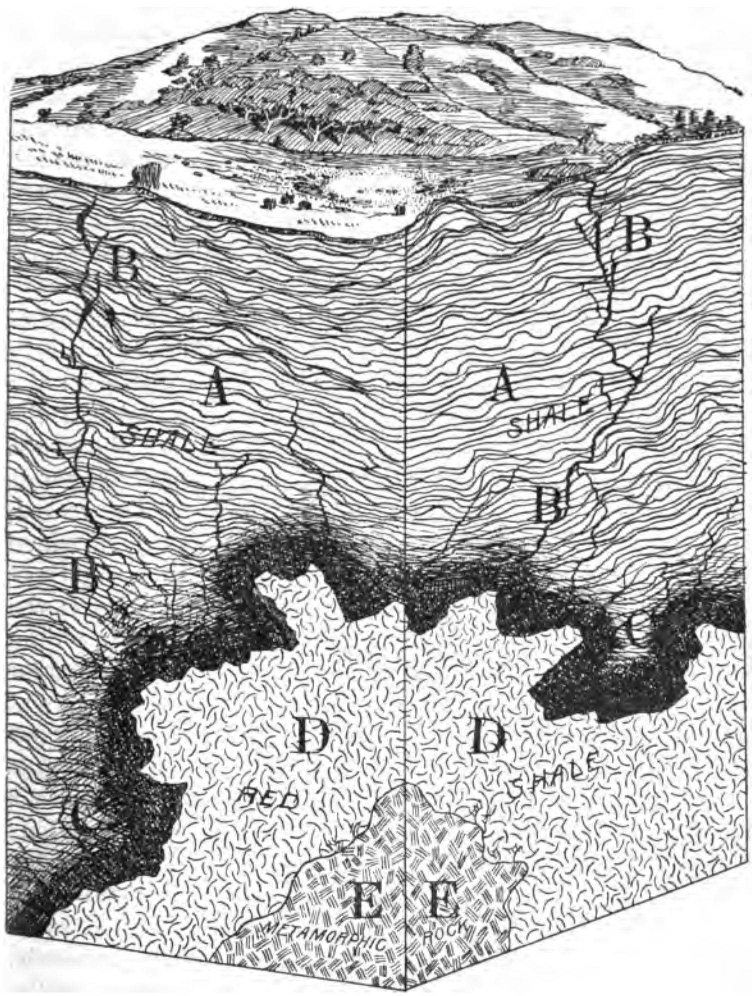


FIG. 9.—PLANO-SECTION SHOWING ASPHALT VEINS.

by the solvent action of water leaching out the cementing material, such as lime, silica, iron, etc.; the capacity of shale for holding oil, or bitumen, by the mechanical bending and cracking of the strata, the cracks affording storage room.

LIMESTONE.—The Trenton limestone is very productive under certain circumstances. In its normal condition it is a compact rock, and then it contains neither gas nor oil; but, over large areas, limestone has been dolomitized, and so transformed into a porous and cavernous rock, in which the gas and oil are contained.

The dolomitization of the Trenton limestone is probably occasioned by the removal of carbonate of lime by the solvent action of water charged with certain minerals, and as the Trenton limestone contains originally a small percentage of magnesia, it gradually becomes dolomitic in character, and, on account of its reduced bulk and crystallization, porous and cavernous.

When water has taken possession of shale in the shape of quarry water, or the shale is saturated with water, it is nearly impossible for oil to eject the water and enter the shale; the reverse is also true, for, when oil has taken possession of the shale, it is nearly impossible for water to enter the shale. This is undoubtedly owing to capillary attraction of the fluids in the shale. When the surface of a capillary tube is greased, it exerts but little capillary attraction upon water, and when a capillary tube is moistened, it exerts but little capillary attraction upon oil. Other rocks act the same as shale; the finer the grain of the rock the greater the capillary attraction, and the more difficult it will be for oil to replace water, or for water to replace oil.

Shale, occupied by water, makes a good incasement for oil and asphaltum.

The retention of petroleum and pissasphalt, in the porous and seamed rocks, cannot be effected without the accumulations or reservoirs having a cover or impervious incasement. This impervious incasement usually consists of unfractured shale or other close-textured rocks, or porous and fractured rocks cemented and sealed with indurated bitumen or other minerals.

When the outcrop of bituminized sand is exposed to the atmosphere for a long time, the bitumen contained in it loses its volatile parts by evaporation and oxidation, turns brown, and is easily pulverized between the fingers. The sand separates from the bitumen, and the bitumen is easily ground to an impalpable powder. This brown asphaltum extends to but a short distance below the surface of the stratum. Beneath the

brown coating of bituminized sand the deposits receive a coating of hard asphaltum, made hard by evaporation and oxidation. The condition of the bitumen in the seamed and cracked shale resembles that which is in the sand. This concreted surface is impervious to the flow of pissasphalt and petroleum oil, and frequently sufficiently tight as to inclose natural gas. In fact, all porous or seamed rocks, when the base of the saturating petroleum is asphaltum, become water and petroleum tight, by reason of the petroleum becoming concreted by oxidation and evaporation; the same as when a tree is wounded by a cut or puncture, the impissated sap soon closes the pores, so that little sap escapes. The surface of the bituminized sands and shales is hard, increasing in fluidity as the bitumen enters the deposit, or is removed from atmospheric influences.

In some deposits, a short distance from the surface will show a petroleum oil of 10° Baumé, decreasing at 1,000 feet to 32° Baumé.

If rather stiff maltha is melted and poured into a hole in a sheet of iron one sixteenth of an inch in diameter, so that it will form a thickness one sixteenth of an inch on each side of the sheet, the sheet being one sixteenth of an inch thick, it cannot be removed with a pressure of water equal to fifty pounds to the square inch. The prodigious pressure necessary to force maltha through the interspaces of sand, or irregular seams of shales, for a distance of several hundred feet, can hardly be imagined. In fact, the salvation of most of the accumulations of petroleum oil in California is owing to this induration of petroleum by oxidation and evaporation.

This impervious coating also protects the oil reservoirs from the entrance of surface water.

The petroleum oil, in passing through the sand or shale, collects the silt and carries it forward. This, also, assists in forming a cover, filling up the places through which the liquid hydrocarbons attempt to escape.

Under great pressure, the petroleum oils are constantly alert to take possession of any space created by the uplifting, or other movements, of the earth; and if these oils are concreted into asphaltum, by oxidation and evaporation, they retain possession. The oil occupying the surface of the water in a formation has an advantageous position to perform this

work, as the formation is more fractured in these parts than in the synclines and the dips of the anticlines.

The cut (Fig. 10) shows strata of bituminized sand on a ridge running north and south, between the Coja Creek and a branch of the Baldwin Creek, seven miles west of Santa Cruz, California. The bituminized sand lies nearly horizontal, and extends from cañon to cañon, through the ridge. The dip of the shales and sandstones of the surrounding country shows that this is the apex of a large dome covering an area of some twelve square miles. Overlying these strata of bituminized sand is a close-textured shale, forty feet thick, and underlying the same is a porous and incoherent sand.

FIG. 10.—C. S. I. CO.'S MINE, SANTA CRUZ COUNTY, CALIFORNIA.

The Coja Creek, lying immediately west of this deposit, is 200 feet deep, and must have taken many thousands of years to form. Redwood trees, proving by their concentric circles to be several hundred years of age, are growing in the bottom of the creek. The impregnation of the sand with bitumen must have occurred before the gulch on either side of the deposit commenced to form through denudation, otherwise the liquid bitumen would have run out of the porous sand. From the horizontality of the surface of the porous sand which underlies the bituminous strata, it must have been filled with water, forming a horizontal plane, upon which the bitumen floated. This, also, must have occurred before the denudation of the gulch on either side. The petroleum must have been under considerable pressure, as it has thoroughly saturated the sand between the porous sand and the overlying shale,

and, where porous places have existed in the shale, petroleum has been forced into them.

Notwithstanding the thousands of years which this bituminized stratum has been exposed to the elements, the bitumen in the interior parts of the deposit is at present liquid, its liquidity being preserved by the concretion of the bitumen on the top, bottom, and sides of the deposit, stopping evaporation, oxidation, and leakage. These strata of sand, when bituminized, contain gold in considerable quantity; whereas, in those portions which are not bituminized, but little gold exists. It would seem that the gold in the bituminized sand was protected from the solvent action of mineral water, the presence of the bitumen in the sand stopping the percolation of mineral water; whereas, in the sands not bituminized, this percolation is permitted, and the gold is dissolved and carried away. But further examination will be required to be positive that such is the case.

Sand rock, sand, and sandstone are composed mainly of rounded or broken grains of quartz of varying form, color, and fineness. The material cementing the grains is either argillaceous, bituminous, silicious, or calcareous, or a mixture of any of these four substances. Some of these sands contain cementing material, some in such a small quantity that they are friable. When found beneath the earth's surface, it is seldom in an incoherent state. When they are porous, they are occupied by either natural gas, petroleum oil, or water (generally of a mineral character), or both of these fluids and gas.

The buoyancy of the oil in associated water is the force which impels the oil upwards. The oil is carried so far upwards that it sometimes escapes at the surface in the form of tar springs, or seepages, and is lost, or it accumulates in porous or seamed strata beneath the surface of the earth. For the reception of the petroleum oil or gas, the sandstone strata are at first made porous by the solvent power of water, which removes the calcareous and silicious cementing material.

Frequently these bituminized sands are jointed, and, although this adhesive and plastic material, when excavated and thrown into a pile, will stick together so that it has to be again mined, it will separate readily at these joints when

being taken from the deposit. The joints are often filled with mineral matter, such as carbonate of lime, deposited by circulation of waters subsequent to the bituminization of the sands. (Fig. 11.)

FIG. 11.—BITUMINIZED SAND SHOWING JOINTS.

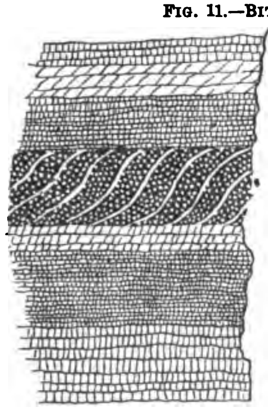


FIG. 12.—BITUMINIZED SAND SHOWING CONTORTED JOINTS.

These joints are probably partly due to pressure, as they seem to have a trend which appears to be at right angles with the line of the steepest inclination upon which bituminous deposits rest, but always nearly perpendicular to the plane of bedding. Some deposits, when jointed in this manner, appear like a row of books upon a shelf.

Fig. 12 shows bituminous strata on the Sisquoc River, in Santa Bar-

bara County. By the movement of the formation, the joints, filled with lime, have been distorted so as to nearly form the letter "S," showing that there has been a considerable movement since the bituminization and jointing of the sand.

Thes trata are often'faulted a few inches at these joints. In the folding of a formation, the shales will be contorted, and the bituminized sand faulted at its joints. The bendings of the bituminized sand are never very small and acute, whereas in shale they are small and acute.

This makes a formation often appear unconformable, but it is the nonconformity made by bending and faulting, and not of deposition.

The argillaceous material cannot be removed like the calcareous and silicious cementing matter; consequently, sands cemented with argillaceous material seldom contain bituminous accumulations to any great extent. When the calcareous and silicious cementing material is removed by circulating water, the oil, if present, occupies the sand. This leaching generally occurs along the line of faults and on the summits of anticlines, as they more readily offer avenues for the egress of water, but may occur along anticlinal dips and in synclines; in fact, in any place where the intricate subterranean course of percolating water reaches the sandstone. When the circulating water has been copious, the calcareous and silicious cementing material has been carried away to the surface of the earth, sometimes forming deposits of sinter, tufa, limestone, or dolomite. When the flow of these waters, charged with carbonate of lime and silica, has been feeble, and the sandstone has again been cemented and made impervious to water, then the flow of water ceases, or finds some other path of escape.

Deposits of petroleum oil, resembling pools, occur in the sandstone stratum in which the circumjacent sandstone is cemented with calcareous and silicious material. The portion of the stratum now occupied by the bitumen was formerly occupied by the carbonate of lime or silica, the lime or silica having been removed by the solvent action of percolating and circulating waters. If the gas and oil are ever removed from these porous strata, they will, in all probability, be again cemented by lime or silica, if water again takes possession and its flow is feeble.

Shale is laminated clay, more or less indurated, splitting into thin sheets along the original laminæ of deposition. In California, the majority of shales are quite soft, being easily cut with a knife.

A large proportion of the oil obtained in California is taken from the cracks and recesses in shale. The strata are arranged around the axis of the anticline in concentric circles. During distortion, occasioned by the uplifting of the strata, there would be an elongation of these concentric strata. If they consisted of non-elastic shale, they would be cracked and seamed transversely to the seams of their bedding. This would occur to a greater extent in the strata farthest from the axis of the anticline. If there was a great weight of superincumbent earth, the cracks and seams would not be so large along the planes of bedding of the shale. Being more acutely bent, the strata on the steep side of an unsymmetrical flexure would be more broken than on the other side.

During their uplifting, the strata on the slopes the farthest away from the axis of the anticline would move slower than those nearer the axis; consequently, one stratum would move upon the other, grinding the shale into plastic mud, and luting seams and cracks, which would assist in forming an incasement of water and oil. This grinding movement also keeps cracks and seams from occurring parallel with and along the planes of bedding of the shale. When the shales are bituminized in their cracks and seams, one tenth of the bitumen is in the seams that occur parallel with the planes of bedding, and nine tenths in the cracks and seams that occur transverse to these planes. Where the shales, the cracks and seams of which are filled with bitumen, which resist the action of denudation better than the shales that do not contain it, are side by side, the latter are worn away more largely than the former, and a valley results, owing to denudation acting unequally. Many bluffs, and prominent peaks and ridges, owe their existence and stability to the bitumen in the cracks and seams of their shales.

When water takes possession of shale, the capillary attraction offers so great a resistance that oil, even under enormous pressure, is incapable of forcing an entrance and ejecting the water. When oil is in possession of the shale, the same resistance is offered to the entrance of water. Shale saturated

with water is a far better covering for petroleum than dry shale. Where the distortion of the strata has been acute, the multiplicity of these cracks and seams makes the storing capacity of these fractured shales very large—in fact, many will be equal in this respect to porous sands. For reasons stated heretofore, the cracks and seams will be wider on the summits of anticlines than on their slopes or in synclines. Owing to the broken condition of the shale, the petroleum has ascended from strata to strata, and not for any great distance through any particular stratum or strata, until the concretion of the bitumen, by exposure to atmospheric actions, assisted by silicious waters, sealed strata from each other.

Silica and Lime.—The hot waters created by chemical heat, held in solution large quantities of silica. When the hot silicious water approached the surface of the earth, it was cooled; the cooler the water became, the less capable it was to hold in solution this large amount of silica. Cooling of the water eliminated the silica, which was deposited in the interstices of the shales, increasing their solidity and imperviousness. There may also be an interchange between the silica dissolved in the water and certain constituents in the sandstone and shale—for instance, carbonate of lime—the silica, having a greater degree of hardness than the substance removed, would be deposited. This silicification is a very frequent phenomenon in these rocks.

If the silicious water circulated through particular strata, the silica eliminated by the cooling of the silicious water, owing to its superior gravity, sank to the bottom of the strata and cemented the same. Strata adjoining the hot, silicious water may be cooler than those in which the silicious water circulates; in that case the cooler strata act as condensers. This action created the strata known as "shells"; the shells often occur on the top and bottom of the sands, and throughout the shales. This silicification, together with the concreting of the bitumen, creates impervious strata, which are capable of holding petroleum oil and natural gas. These silicifications, when formed in strata in which bitumen occurs, are colored black. Their color is destroyed by burning, proving that it is owing to organic material.

Silica, in a very fine condition, is frequently attracted to

some organic or inorganic nucleus which has grown in successive layers or bands, often of different colors. In a similar manner the small silicious particles, separated from hot, silicious solutions, are attracted by the incasements of porous, or partly porous, and seamed strata.

Lime is controlled usually by the same conditions and laws as silica. Large masses of shale and sandstones have been calcified and salicified near the bituminous deposits in California.

Deposits of bitumen and petroleum oil are controlled by the line of permanent water. Below the level of the ocean, all cracks, seams, fissures, and interspaces are permanently filled with water. Above the level of the ocean, and below the beds of streams, the supply of water in these spaces is fairly permanent. Above the beds of streams the supply of water is dependent upon the rainfall, and the degree of freedom with which it leaves the formation.

Pervious and impervious strata modify the above conditions. Permanent water may be replaced or occupied by a deposit or column of bitumen, petroleum oil, or natural gas. When the underlying water, which supports the oil, is released by the uplifting of a formation above the permanent water by orogenic movements, the water leaves the formation, and the oil drains into the voids formerly occupied by the water, and, possibly, reaches the surface by the same avenues taken by the water, and is lost or resinified to asphaltum. Frequently the porous strata accumulations of bitumen have resulted through the drainage of oil from a higher and large area of porous rock into a lower porous stratum.

The bituminized sands on the mesa deposit, on the Sisquoc Rancho (Fig. 13), show the drainage action. They are drained into a centrocline, the sides of the centrocline afterwards having been carried away by denundation; the water which buoyed up the oil escaped, and the oil slowly sought the bottom of the centrocline. The sands forming the uppermost edge of the centrocline have, to a great extent, lost their bitumen; as soon as the bitumen leaves the sand, it falls into an incoherent mass, and is rapidly washed away by rains. The existing bitumen, in consequence of the long distance traveled, has become viscous, principally through oxidation and evaporation.

This drainage is still slowly progressing, as in hot weather

balls of nearly pure bitumen form on the surface of the sands in the lower part of the deposit.

South of Asphalto, in Kern County, the bitumen has reached the bottom of the syncline by drainage, and is now gradually descending through the syncline, as through a ditch. Although this occurred ages ago, this drainage is still in process.

What evidence is there that water circulates and circulated through these formations? The presence of calcareous tufa at the outcrops of the strata; the presence of bitumen in the cracks and seams of the shales, and in the interspaces of the sands floated up by associated waters—if the bitumen was forced up exclusively by gas, it would not have been so evenly and generally disseminated throughout the shales and sands; springs of water accompanied by natural gas and oil, issuing from the outcrop of strata which dip towards the source of the water, and the absence of these springs from the outcrop of strata which dip away from the source of the water; the seams of hard shale, called "shells," silicated by infiltrating silicious waters; nothing but molds and casts of fossil shells, the carbonate of lime

FIG. 13—MESA DEPOSIT, SISQUOC RANCHO. A A A—Bituminized sands.

having been removed in solution in water. Near the outcrops of these strata, in the creek and river beds, the sands and gravels are cemented together with carbonate of lime, forming conglomerates.

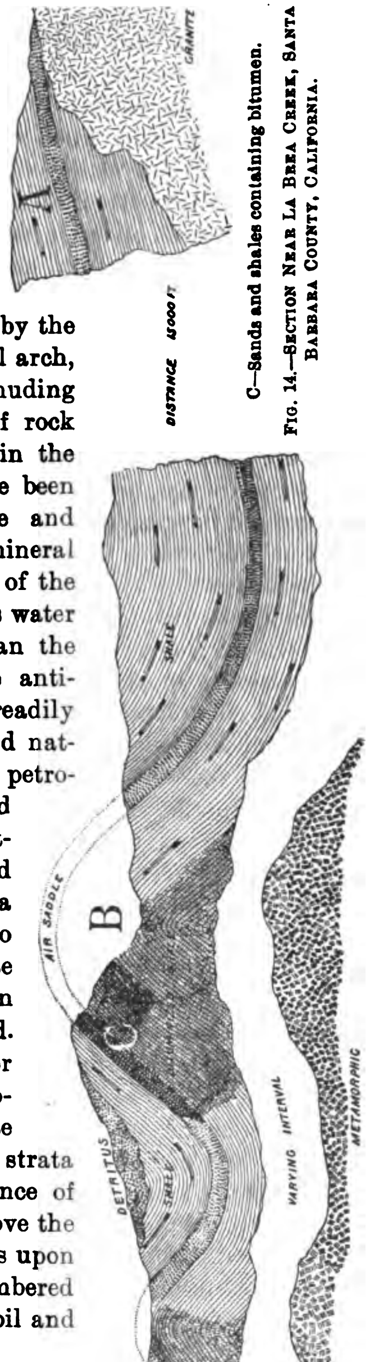
What is the effect on deposits and accumulations of bitumen by circulating waters, fresh and mineral? Petroleum oil, when exposed for a long time to water containing sulphuretted hydrogen, is resinified by being sulphurized; especially is this true where the sulphur is liberated by decrease of pressure, or by the oxidation of the hydrogen. The sulphurizing of petroleum oils by sulphuretted hydrogen is a chemical combination, but, if only a mechanical combination, it is so intimate as to resemble a chemical combination.

Petroleum oil will be oxidized when exposed for a long time to water containing oxygen, or atmospheric air. Oxidation converts the oil into petrolene, and greatly increases its gravity. As slight quantities of petroleum oil are dissolved in fresh water, the lighter parts are dissolved; consequently, the effect of circulating fresh water is to carry away the lighter parts of the oil, leaving the heavier parts behind. Water saturated with salts has but little effect on petroleum oil. Sometimes the salts, through the agency of water, are mechanically and intimately mixed with the bitumen, so as to render their separation difficult.

Besides these chemical effects of water on the bitumen, water exerts the following described hydrostatic and hydraulic effects: In cases where strata are rendered leaky by denudation, and water is ascending to the surface through the same, the petroleum oil is floated out on the surface of the water and lost. Meteoric water, which falls on higher ground, penetrates the earth, sometimes to great depths, through inclined and porous strata, or through fissures, cracks, seams, and joints of rocks; and, after flowing a distance, sometimes the distance being very great, it must ascend through permeable strata to the surface, or, hidden, find its subterraneous way to the sea. The course of water flowing underground is not strictly analogous to that of a river on the surface, there being, in one case, a constant descent from a higher to a lower level, from the source of the stream to the sea; whereas, in the other, the water may at one time sink below the level of the ocean, and afterwards rise high above it, by hydrostatic pressure, due to the superior level at

which the rain-water was received, and the incasement of permeable strata by impervious strata.

It must be borne in mind that the circulation of water through the rocks can be extremely slow. On account of the broken condition of the rock on the anticlines, caused by the acute curvature of the anticlinal arch, and its greater exposure to denuding agents, far greater quantities of rock have yielded to erosion than in the synclines, where the rocks have been hardened by lateral pressure and cemented by infiltration of mineral waters. This broken condition of the rocks of the anticlines permits water to enter them more freely than the synclines or the slopes of the anticlines, and also permits more readily the escape of petroleum oil and natural gas. The accumulation of petroleum oil must have commenced when these rocks were but slightly undulated. The former and ancient features and state of a formation should be taken into consideration, as well as those existing at the present time, in the examination of an oil field. If there is no opposing force or intervening obstacle, gas, petroleum oil, and water distribute themselves in porous or seamed strata in accordance with the difference of their gravity. The gas lies above the petroleum oil, and the oil floats upon the water. It must be remembered that, under ordinary pressure, oil and



C—Sands and shales containing bitumen.

FIG. 14.—SECTION NEAR LA BREA CREEK, SANTA BARBARA COUNTY, CALIFORNIA.

water do not mix, and that the gravity of petroleum oil is less than that of water, but for which little would have been seen on the face of the earth. If petroleum oil is introduced into the bottom of a vessel filled with water, it will rise to the top of the water; and if water is placed on the surface of the oil, it will sink to the bottom of the oil.

The pressure of water is exerted below the petroleum oil, and the pressure of natural gas above. Porous strata, incased in nearly impervious strata, must be considered as conduits for the fluids, petroleum oil and water. When petroleum oil and water flow in the same direction, the porous and seamed strata are liable to be barren of oil. Where the oil and water flow in opposite directions, the porous or seamed strata are liable to be fruitful with oil.

Many years ago, before the denudation occurred, these strata were incased in an impervious cover; the right-hand dip of the anticline was towards the mountains; meteoric water, falling on the mountains, entered the porous strata at A (Fig. 14, page 57), and finally flowed up the right-hand dip of the anticline, B, as shown by the arrows, being impelled forward by hydrostatic pressure in the higher levels of the mountains; and the associated oil which entered these strata, by its inferior gravity when compared with water, flowed in the same direction as the water; therefore, this dip of the anticline is barren of bitumen. In the left-hand dip of the anticline, B, the water flowed downward, impelled by gravity, and, probably, hydrostatic pressure, seeking an exit as springs in the valleys, or, unseen, found its way to the sea; the oil, by its inferior gravity, was buoyed up by the water, or ascended in a contrary way to the flow of the water; consequently, the pores and seams in this dip are filled with bitumen. These same conditions exist in the Zaca anticline, Las Pozitas anticline, lying west of Santa Barbara, and at Summerland, and many other places.

The following is an exception to the accumulation of oil in the dip remote from the source of circulating water: Petroleum oil is nearly always accompanied by natural gas. If the porous or seamed strata, serving for conduits for water or oil, have vertical curves or summits, and such summits are sufficiently tight to hold the gas, in time the gas will accumulate in such summits and occupy a considerable part of the sectional area, and it will continue to accumulate until

the velocity of the water or oil is sufficient to carry the gas forward, and down the incline. If the pressure never reaches such a point as to effect the removal of the gas, the flow of the water or oil will be more or less obstructed; and, finally, if the gas is not removed, or does not escape, the flow of the water or oil ceases. In this case, oil will be found in the dip of the anticline which is towards the head, from which the water emanates.

Fig. 15 shows alternating beds of different sands, all of which are bituminized.

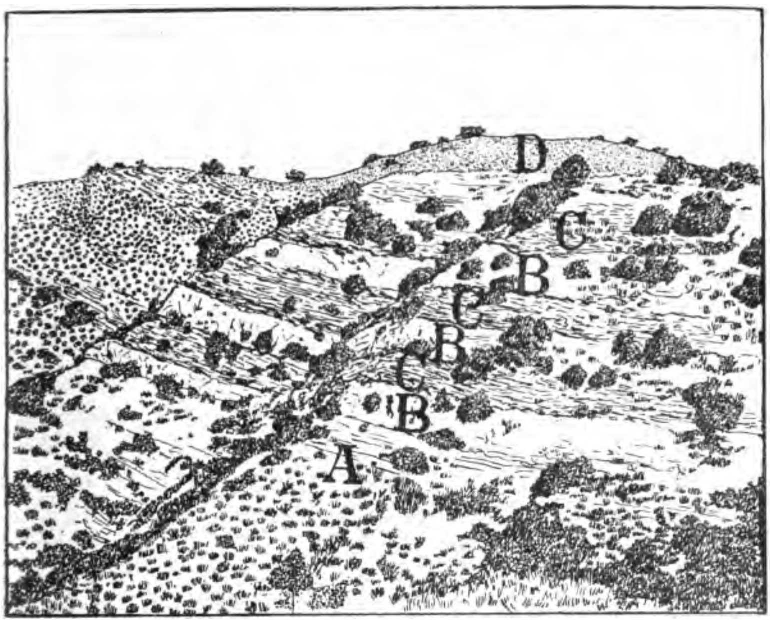


FIG. 15.—ALTERNATING BEDS OF DIFFERENT SANDSTONES.

Strata C C C are formed of coarse quartz sand, containing round pebbles of hard rocks, such as quartz. They do not contain many fossils.

Strata B B B are formed of fine, muddy sand, containing lenticular pebbles of shale. These pebbles have been silicated, forming chert, but their surfaces still retain the appearance of shale, and they have the lamination of shale.

This silicification must have occurred before these sands were bituminized. This silicification was, probably, effected by the

infiltration of hot silicious water. The creation of this water was, probably, through the agency of metamorphism, which preceded the distillation of petroleum from carbonaceous matter by the heat of metamorphism.

In the figure, A represents fine shale with few fossil shells; in places it contains fossil fish-bones. The cracks and joints at right angles with the planes of bedding are frequently filled with bitumen.

No cracks at right angles with the plane of bedding could have existed in these shales until they were contorted; therefore, these cracks were bituminized after the folding of the formation had commenced. Neither could bitumen have ascended through these shales before they were cracked or jointed, for when these fine shales contain quarry water, they are impervious to oil.

These different strata, B'B B and C C C, are conformable, and do not pass into one another by gradation; the lines between them are clearly marked. The muddy, fine sand does not weather as rapidly as the coarse sands; consequently, their faces of exposure are nearer verticality than those of the coarse sand.

The different strata must have been derived from two formations, one being composed of altered rocks, and the other of unaltered rocks, and the changes in the derivation of the sediments composing this formation, from the altered to the unaltered rocks, were quickly made, either by a change in ocean currents or by the sudden uplifting of the land.

These strata of sand, described above, are situated on the Tinaquaic Rancho, in Santa Barbara County. The character of the bituminized sands near Santa Cruz is very different. They contain few round pebbles of hard rock, and no lenticular pebbles of shale. They are clean quartz sands, of varying fineness, and were, probably, formed by the disintegration of granite. They do not contain many fossils, and contain gold in notable quantities.

That sudden upliftings did occur, is shown by the terraced structure at the Santa Cruz bituminous deposits, there being three terraces clearly defined. The uprise, or face, of the first and second terraces was partly cut from the bituminous sands, showing that the sands were contorted and bituminized before these terraces were made by the sea.

When these bituminized strata rose above the line of permanent water, the flow of the bitumen was, and is at the present time, down the dip of the strata towards the sea, and the sands in the upper part of the dome, which were vacated by the bitumen, are calcified, the lime probably being derived from overlying calcareous beds which have been removed at this place, but which exist farther towards the east.

The following is a description of the only explored submarine oil fields in the world:

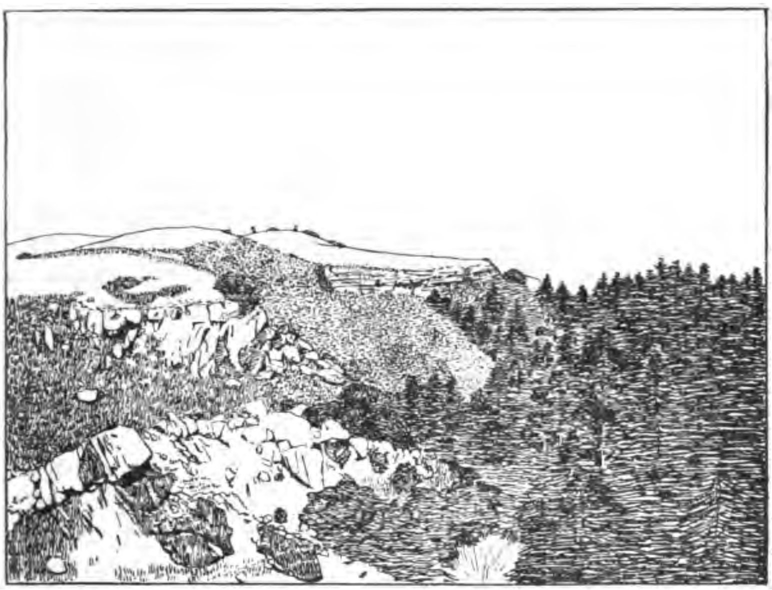


FIG. 16.—BITUMINOUS SAND DIPPING TOWARDS THE SEA.

In Santa Barbara County, California, the Summerland oil-bearing strata consist of a fine-grained sand, incased in strata of clay or clay slate. When near the oil-bearing strata, the clay, or slate, is of a bluish color, owing to its being slightly impregnated with bitumen. The sands and shales form an elongated dome, the longest axis of the dome being from east to west, running nearly parallel with the coast and parallel with the trend of the Santa Ynez Mountains. Near the eastern end of the dome the formation dips about S. 20° E., at an angle of about 50°, whereas, on the western end, the sand dips

about S. 10° W., at an angle of about 60°. The general dip of the sand is southerly, at an angle of about 40° or 50°.

The first discovery of the hydrocarbons in this field was made on the south slope of the anticline. At this place there was a fumarole, some twenty feet in diameter, from which warm carburetted and sulphuretted hydrogen gas escaped. No vegetation grew on this place, owing to the sulphur fumes. The Spaniards had a legend that a man was killed there, which, according to them, accounted for the fact that nothing grew upon it. A pipe was sunk in the fumarole, and capped, and a two-inch pipe inserted in the cap, when the gas was permitted to flow through the pipe. It did so with considerable pressure, and, when lighted, gave a flame ten feet in length. On a line nearly east and west with this fumarole, other wells have been bored, which have yielded gas. The gas has been employed for domestic purposes.

South of the gas wells, on a nearly east and west line, are a line of oil wells; they are from 130 to 250 feet deep. The first oil obtained in the field was from a well dug 90 feet in depth, which produced three or four barrels daily. The oil is black or dark green, and is of a very heavy gravity, being 11° to 16° Baumé.

Judging from other oil fields, the northern dip of the sands of this anticline will be barren. Meteoric water, falling on the higher ground of the Santa Ynez Mountains, which at places reach an altitude of 3,600 feet, penetrates the earth through inclined and porous strata, or through fissures, cracks, seams, and joints. After flowing through subterranean passages, it must ascend through permeable strata to the surface, or, hidden, find its way to the sea. As the Summerland anticline forms a barrier between the Santa Ynez Mountains and the sea to the passage of the water, it is forced by hydrostatic pressure to ascend through the north dip of the sand of this anticline. Owing to its inferior gravity, the petroleum oil is floated upwards by the water, and is lost on the surface of the earth, or is carried over to the south dip of this anticline. With the southern dip of this anticline it is different; the flow of the water is downwards, the oil remaining on top of the water by its buoyancy.

Owing to the large amount of organic matter in the shales underlying the Summerland oil field, if any iron was present

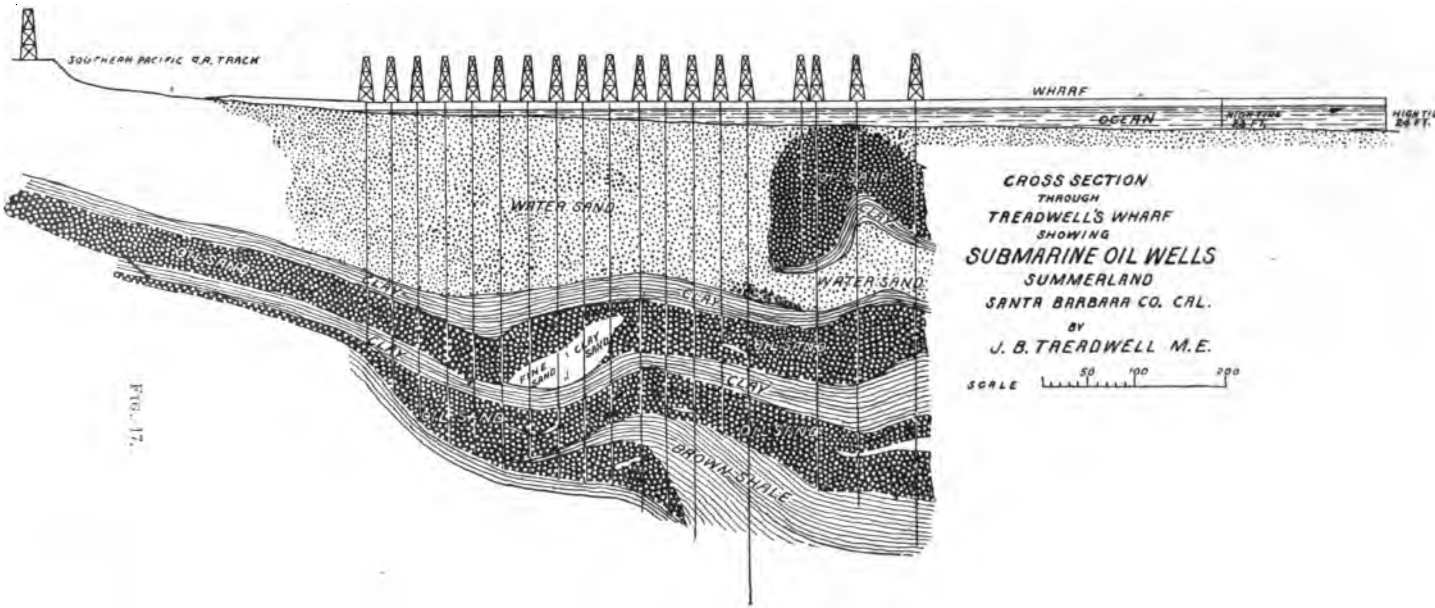

SOUTHERN PACIFIC R.R. TRACK
WHARF
OCEAN
HIGH TIDE 24 FT.
WATER SAND
CLAY
FINE SAND
CLAY SAND
OIL SAND
BROWN SHALE
CROSS SECTION
THROUGH
TREADWELL'S WHARF
SHOWING
SUBMARINE OIL WELLS
SUMMERLAND
SANTA BARBARA CO. CAL.
BY
J. B. TREADWELL M.E.
SCALE
50
100
200

FIG. 17.

during their deposition, it must have been in the form of ferrous carbonate. The carbonate of iron imparts a bluish or greenish color to the deposit. When the shales, in which carbonate of iron exist, are turned red, it is caused by chemical heat. The presence of red shales below the Summerland oil strata, as revealed by a well drilled to the depth of 1,000 feet, and the high temperature of the natural gas, show that chemical changes are in active operation at present beneath this field. It is probable that sulphur compounds, liberated by chemical heat in the shales, have resinified the petroleum oils of Summerland, which will account for their great gravity.

A wharf has been extended into the sea towards the south, and at nearly right angles with the trend of the shore. From this, productive wells are drilled in the bottom of the ocean, yielding a petroleum oil somewhat lighter than the numerous wells upon the shore.

Fig. 17 (page 63) is a profile made by J. B. Treadwell, M.E., showing the character and structure of the rocks encountered, and the number of wells which have been drilled.

The illustration Fig. 18 shows a formation lying east of Zaca Creek, in the county of Santa Barbara, California. A A A is bituminized sand, forming the south dip of an anticline; underlying the bituminous sand are bleached shales, B B B, and below the shales are metamorphic rocks, quartzite, and serpentine. At one point the metamorphic rock has closely approached the bituminized sand. At this point the bitumen has been removed from the sand, and the sand is calcified and silicified. From the attending phenomena, it would seem that these sands were bituminized before metamorphism reached them.

This sandstone, when not reduced by erosion, is nearly 300 feet in thickness, and, like a mantle, covers a large part of the territory lying between the Santa Maria and Santa Ynez rivers, the Pacific Ocean and the Alamo Pintado Creek, in Santa Barbara County, some 600 square miles. In the summit of the domes, and in the dip of the anticlines which are farthest away from the mountains which are higher than the summits of these anticlines, the sands are sometimes bituminized. Extending towards the northwest, from the place shown in the illustration, are sands containing millions of tons of bitumen. These bituminized sands are very prominent, forming high

bluffs. Throughout the area which this upper sand covers, there are places where these sands are silicified, in others calcified.

On the south slope of the Santa Maria Valley, and in some other places, these sands are uncemented, and have been formed into sand hills through the shifting of the sands by water and the winds. Also, scattered throughout this area, there are a number of sulphur blows, mineral springs, and places where natural gas escapes in large quantities. On the slopes of Mount Solomon, asphaltum is injected into the formation surrounding subsidences. Veins of asphaltum also occur on the Jonata Rancho. White leached shales, and shales burned to various tints of red, occur in large masses. The shales and sandstones in this area are fairly conformable.

On the Sisquoc River there is another exposed sand which is bituminized, and which is, geologically, about 1,000 feet lower than this upper sand, and is separated from it by a bed of shale. How thick

FIG. 18.—FORMATION LYING EAST OF ZACA CREEK, SANTA BARBARA COUNTY, CALIFORNIA.

this lower sand is cannot be positively determined, but, judging from its exposures, it must be over 300 feet thick. If this sand covers the same area as the upper sand, which it is reasonable to suppose it does, there is no reason why it should not contain, in its domes and the dips of its anticlines, millions of tons of bitumen, which, on account of being excluded from the atmosphere, should be in the form of petroleum oil, and which could be obtained by the sinking of wells.

If it be true that the bitumens are derived from terrestrial and marine vegetation, deposited in sedimentary strata, and then changed to carbonaceous matter, which was afterwards distilled by the heat of metamorphism, then we may expect to find petroleum oil or other bitumens in unaltered rocks lying above the metamorphic rocks, irrespective of the age of the unaltered rocks.

A number of facts that have been presented in the preceding pages tend to prove that this is the origin of bituminous accumulations in California.

A conclusive determination of the origin of the bitumens is of great importance, for if the origin is as set forth in this monograph, explorations can be continued to such depths as to reach the metamorphic rock, and these explorations may be successful, especially so if the bitumens are found near the surface; but if the bitumens are indigenous to the rocks in which they are found, the depth to which they may extend is uncertain.

PHENOMENA ATTENDING THE ACCUMULATIONS OF BITUMEN.

The phenomena described in the succeeding pages are connected with the accumulations of bitumen as observed in California. All of these phenomena are generally found in one formation, and so frequently together and in conjunction with bituminous deposits that it must be considered that one is the result of or is closely connected with the other, especially when it is known that one can produce or is the direct effect of the other.

These phenomena would not be important in prospecting for a primary or stationary mineral deposit, but will be of great assistance in the discovery of a derived and migratory fluid such as petroleum oil.

When their influence, relation, and position in regard to bitumens or bituminous deposits are determined and more generally understood, they will materially assist in the discovery and development of such deposits.

Red shales, earth subsidences, mineral and hot springs, leached shales and sandstones, silicified shales and sandstones, and accumulations of bitumen accompany one another and are traceable to metamorphic action.

Normal Shale.—This is an impure hydrous silicate of alumina. It contains about twenty per cent of alumina, about seventy per cent of silica, and, in variable and small amount, protoxide and carbonate of iron, lime, soda, magnesia, potash, and other minerals, and organic substances. It contains fossils in greater or less number. Color of the shale is usually dirty white to brown, but sometimes of other colors. It gives out an earthy odor when breathed upon, and is readily scratched with the finger nail. When wet with water it can be kneaded into a plastic mass. It is clay consolidated by pressure, and is capable of being split into thin layers along the original laminæ of deposition. When exposed to atmospheric influences it rapidly disintegrates.

Normal Sandstones.—When first deposited by water, these consist of incoherent grains of silica of different fineness. The grains are more or less rounded by attrition, the result of their transportation by water. They may contain fragments of other rocks, and they may contain in small quantities lime, magnesia, potash, soda, a number of other minerals, and organic substances. After deposition, the cohesion of the grains may be effected by pressure alone. They may contain fossils in greater or less number. Sandstones are of many colors.

Both shale and sandstone at the time of their deposition may be cemented by ferric, calcareous, silicious, or other material; but this cementation usually occurs subsequent to their deposition, when fresh or mineral waters commence to circulate through them.

Alterations in the shale and sandstone, effected by fresh and mineral waters, heat, and in other ways, will be described hereafter.

The accompanying sketch and sections (Figs. 19 and 20) show a portion of the San Rafael Mountains, situated in the northern end of Santa Barbara County, State of California.

being uplifted. In subsidences, cracks in the rocks which approach horizontality are widened and the rocks fault on these cracks. These cracks are not widened in an upward thrust.

Subsidences are not faults; they usually form a centrocline, and the depression is always greater at the center than at the periphery; many of the depressions are bowl-shaped, and are called "ollas" by the Spaniards. Many of these depressions now form the beds of lakes. In the same area these subsidences are repeated many times. The entire area does not subside at the same time, and it is, therefore, greatly broken and crushed; nor does the movement take place at one time, but may continue for years.

By the time these shales and sandstones come in contact with metamorphic heat they are badly broken and contorted, owing to the action of subsidence, and they are further warped and twisted by the heat of metamorphism.

At a depth of 500 to 1,000 feet the subsidence due to coal workings amounts to about fifty per cent of the thickness excavated; sometimes these subsidences continue during as much as four years. The contraction in a formation composed of equal volumes of shales and sandstones when burned to a porcelanite, is about one tenth of its original volume. A formation burned to a depth of 1,000 feet would give a subsidence on the surface of 100 feet in depth, or, taking the amount of subsidence as is shown in coal workings, would give a subsidence of 50 feet in depth.

The red shales and porcelanites previously described nearly always accompany these subsidences. If the interspaces existing in these red shales were filled with soluble silica, they would become jaspers of many colors.

The presence of comminuted red shale in the oils at Summerland, Santa Barbara County, California, and the striking of red shales at the same place at a depth of 1,000 feet, show that these shales exist at great depths.

Scattered throughout Santa Barbara County are over one thousand acres which have undergone subsidence, and some of which are still subsiding. The amount of depression is from 20 to 60 feet, with an average of 40 feet, and there may be many more acres which have undergone subsidence that have escaped observation, or which are or were not visible on the

surface, or, if visible, all signs of the subsidence have been obliterated.

Near the north line of the Sisquoc Rancho, on La Brea Creek, Santa Barbara County, the bluff on the west side of the creek is over 300 feet high, and over a mile long, and covers an area exceeding three hundred acres. The entire bluff is badly broken and contorted, and shows evidences of subsidence, even now going on.

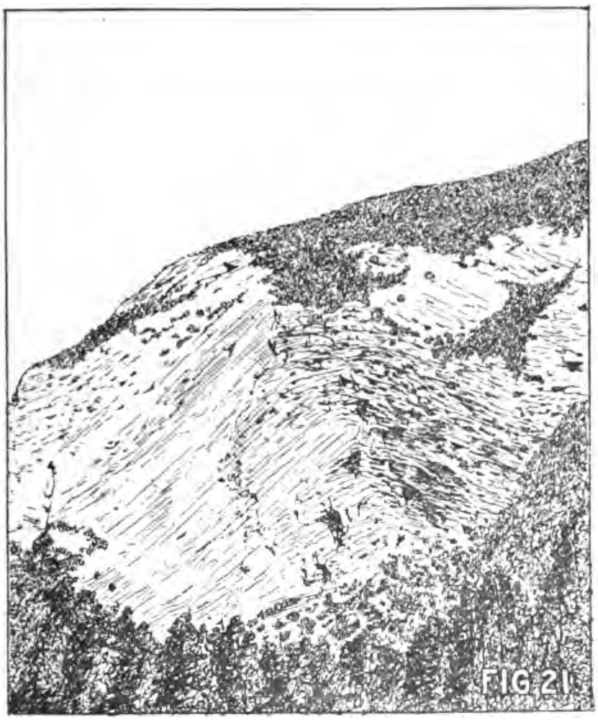


FIG. 21.—SUBSIDENCE, LA BREA CREEK.

Chemical heat reddens and bakes and vitrifies the shales at the bottom of the bluff. The surrounding shales are blackened with carbonaceous matter. Fig. 21 shows the southern end of the bluff. Surrounding this subsidence are hundreds of acres of shales which have been silicified.

In the vicinity of nearly all these subsidences, burned and leached shales and sandstones are found.

The breaking and contortion of the metamorphic rocks have

been attributed to the dynamic force exerted in the uplifting and plication of the mountains. While this force is responsible for this broken and contorted state in part, the greater part must have been effected by subsidence and the warping of the rocks by the heat of metamorphism.

The curvature in the altered rocks is too acute and in the wrong direction, and the fragments of the rocks bent too small, to have been made by the uplifting of the rocks.

Attending the uplifting and the metamorphism of mountains there must have been subsidences of the superincumbent unaltered rocks to fill the space caused by the contraction of the rocks through the action of heat.

The breaking and division of the unaltered rocks lying above and adjoining the places where metamorphic action is in progress facilitate metamorphic changes. It is like the placing of broken coals upon a fire: the interspaces between the pieces permitting the circulation of gases, minerals, and heat.

WATER.—Through its inferior gravity, petroleum oil ascends through water from the depths of the earth, and either forms bituminous springs upon the surface of the earth, or, by its buoyancy, floats upon the water and is stored in the upper parts of porous or seamed strata. The movement of subterranean water is indicative of the movement of oil. Besides these offices, the influence which thermal waters holding silica and other minerals in solution have exerted in many rocks is a question closely connected with the accumulations of the bitumens. All deposits precipitated from water—lime, silica, etc.—may become the cementing substance of shale or sandstone; and, again, all substances cementing or composing rocks which are soluble in water are liable to be leached from the rocks by percolating water. There may be mineral springs without the presence of bitumen, but there are no springs of bitumen that are not accompanied by mineral waters.

Southwest of the metamorphic rock shown in Fig. 19 are sandstone strata, and farther to the west is shale. The sandstone, where it adjoins the serpentine, is snow white. Hot alkaline and acid waters entered these shales and sandstones and dissolved the bases contained in them, also dissolving a quantity of silica. These waters cooled as they neared the surface. The silica would have been deposited had these

waters not encountered a flow of meteoric water, which greatly diluted the hot solution. This increased volume of water made it possible for the silica and bases to be held in solution and be carried away to the sea.

The shales become darker as they go from the altered rocks, until they finally assume the color of normal shale. In places these leached shales have a width exceeding one mile.

The arrows in the sectional views indicate the direction in

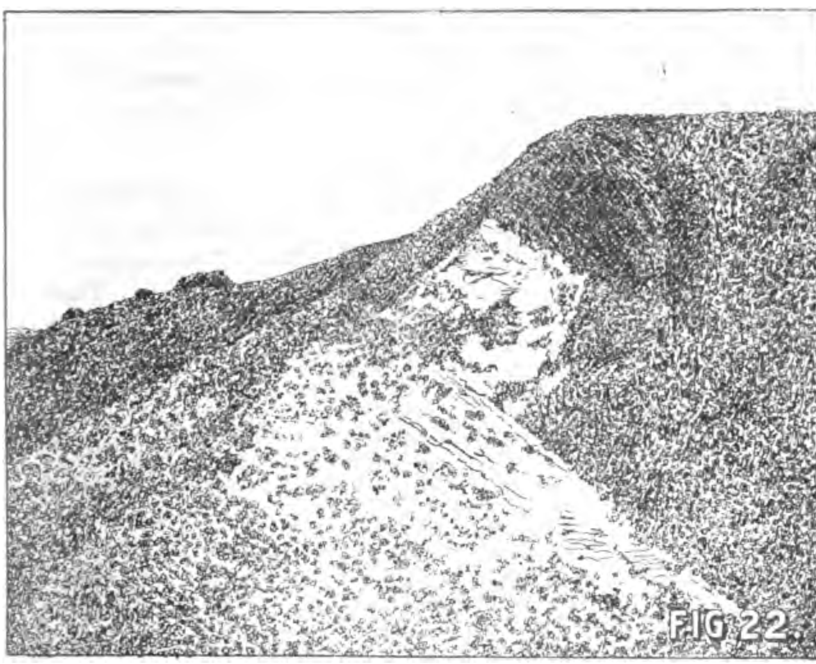


FIG. 22.—CONTACT OF LEACHED SANDSTONES AND SERPENTINE.

which the water flowed and the general direction in which it now flows. The geographical configuration of the country shows that the waters flowed in this direction, as higher mountains lie to the north of the formation shown in the sectional views. The finding of bitumen in the southern dip and the absence of the same from the northern dip of the anticline shown in section C D is additional proof that waters flowed in the direction shown by the arrows. (See Fig. 20.)

Near the serpentine all fossil shells are removed from the shales and sandstones by the solvent action of mineral waters,

and the casts and molds are obliterated through the incoherency of said sandstones and shales, and also by the removal of the coloring from the darker material that usually replaces the part formerly occupied by the shell. At a distance of a thousand feet or more from the serpentine, the same stratum that adjoins the metamorphic rocks contains casts and molds of fossil shells, while still farther away fossil shells exist.

The whitened shales have a porous structure, and are very light compared with normal shales. They can be easily ground between the fingers, owing to the removal of soluble material which once occupied the pores.

Shales and sandstones leached of all bases, such as lime, magnesia, metals, etc., are but slightly coherent and are easily eroded.

Jaspers.—The metamorphic rocks shown in the sketch consist principally of jaspers, or shales, and sandstones partly converted to jaspers. They have a hardness of 7 and a specific gravity of 2.55, and break with a conchoidal fracture. Their prevalent colors are yellow and brownish red of various shades, sometimes nearly black in the seams, and sometimes a greenish white. The darker jaspers often have a resinous luster, but are generally dull.

The transition from shale to jasper is plainly visible; all gradations from unaltered shale to jasper will occur within a distance of a few feet. A portion of the jaspers retains the form of shales, with the exception that they are contracted and distorted by heat. Sometimes they are burned so as to form a solid mass. After burning, they have been silicified with amorphous silica, filling minute cracks and spaces in the jaspers.

The brownish-red jaspers show unmistakable signs of having been burned. They are warped, contracted, broken, and vesicular, showing all the structural conditions that shale does when artificially burned in large masses.

The whitish-green jaspers do not show all these signs of burning, even when in immediate contact with the brownish-red jaspers; but the shales, between which and the brownish-red jaspers these whitish-green jaspers lie, are contorted by heat, and next to the whitish-green jaspers are discolored by oxide of iron.

The vesicular condition only occurs when the brownish-red shales are apparently greatly burned.

In places these brownish-red jaspers closely resemble the jaspers that are the most burned and which are produced by chemical heat near the surface of the earth, and probably are produced by the same metamorphic actions, but on a greater scale.

Pockets containing burned shales not exceeding eight inches in diameter are found in unaltered shales near the surface, which closely resemble some of the jaspers that are in the large mass of metamorphic rocks shown in the sketch (Fig. 19).

It might be expected that, through metamorphic agencies, jaspers might be formed in a large space, but it is remarkable that they can be formed in a space six inches in diameter.

FIG. 23.—OPEN SEAMS AT RIGHT ANGLES TO PLANES OF BEDDING.

Overlying the serpentine and jaspers at J (see Fig. 20) are chemically burned shales; these burned and red shales are previously described.

In Santa Barbara County these red shales cover a large area.

Frequently, in the jaspers, seams and cracks approaching horizontality are closed, while those approaching verticality are open to the extent of the contraction of the rocks during burning. (See Figs. 23 and 24.) The closing of the horizontal cracks and seams may be due to the weight of the metamorphosed rocks, but it must have been augmented by other superincumbent strata. The opening of the vertical seams and cracks must have occurred at the time they were

metamorphosed, showing that there was no great lateral pressure on the rocks during or since their change.

The open cracks and seams are either with, or at right angles with, the plane of bedding of the rocks. When the plane of bedding is nearly horizontal, the open cracks are nearly vertical; when the plane of bedding is nearly vertical, the open cracks are along the plane of bedding.

There are three important changes during the production of jasper, or chert, from shale, viz: leaching, baking or burning, and silicification, and these changes occur in the order given above.

FIG. 24.—OPEN SEAMS WITH PLANES OF BEDDING.

The leaching of lime, magnesia, and other bases by percolating hot waters leaves a light and porous rock, consisting principally of insoluble silica and alumina.

The porous condition of the rock permits the circulation of heat and hot gases; this circulation of heat and gases is also aided by the breaking of the formation through subsidence.

When burnt by chemical fires these shales are of many shades of pink, red, reddish brown, white and yellowish white, and are sometimes black, this color being caused by the presence of carbonaceous matter. Some of these shales are fused and are of a brownish red to black; by fusion they

became impervious to fluids, while the remainder of the shales remain more or less porous.

Besides the cracks caused by earth movements there are numerous small cracks caused by the burning and breaking.

One layer of jasper is a bad misfit with the adjoining layer. Sometimes a piece of a layer of jasper a few inches in length will be warped in one direction, whereas an adjoining piece of a layer will be warped in a contrary direction; some are acutely bent, but the layers of jasper seldom fit perfectly with one another. Nothing but baking and burning could create this almost universal misfit in the layers.

After the jaspers are hardened they cannot be contorted and bent. They would break before bending, and if they were contorted and twisted when in a plastic condition they would probably exhibit slickensides and would have but few wide seams and seams of irregular width and would not be vesicular.

No slickensides are to be seen between the layers, the surface of these layers being nearly always rough. The greatly contorted, bent, and roughly seamed condition of the jaspers must have been occasioned by heat which baked, burned, fused, contorted, cracked, warped, and hardened them and made them vesicular.

Subsequent to their burning the small vesicles and cracks in them were filled with chalcedonic silica. On account of their burning and silicification they greatly resist weathering.

Subsequent to their leaching, burning, and baking, in some of these burned shales the vesicles produced by fusion, and the small cracks and pores and numerous minute round and oval areas, have been filled with soluble silica deposited from circulating silicious waters, forming jaspers and cherts.

These spaces are usually filled with silica, which has a different color from the ground mass of the rock, the colors usually being white and of various shades of red or brownish red.

Sometimes these interspaces have been filled with bands of different colored soluble silica, the bands running parallel with the walls of the spaces.

The interstices in the strata of sandstone shown in section E F (Fig. 20) have been filled with soluble silica, making a hard, compact rock; whereas, the same strata a short distance to the east and west consist of sand cemented with bitumen.

SERPENTINE ROCKS.—On the periphery of the jaspers, and between the jaspers and unaltered rocks, are serpentine rocks; also resting upon the jaspers are isolated bodies of serpentine rocks. All gradations from shale to serpentine rocks can be seen. Shales having a slight bluish-green tint can be obtained; also pieces of the shale partly converted into serpentine rock, one part being serpentinous and the other shale. The serpentine rock lying on the surface of the jaspers would have a tendency to prove that the said serpentine is not eruptive, but metamorphic. Serpentine is seen in every stage of passage from argillaceous sandstone, shale, and jasper to perfect serpentine itself.

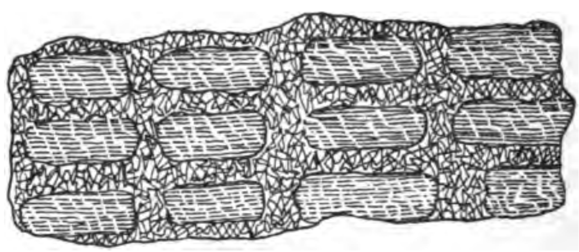


FIG. 25.

The spaces between the irregular but somewhat cubical fragments of jasper, which are arranged in rows after being converted to jasper from shales, are filled with serpentine rock, and these fragments are frequently partly rounded by the alteration of the jaspers to serpentine rock. The lined portion of the cut (Fig. 25) indicates unaltered jasper, and the remainder is serpentine rock. The rounding of the cubiform fragments of jasper represents an incipient decomposition of the same.

The serpentine rock being next to the unaltered rocks, which at one time were saturated with mineral water, the said unaltered rocks would permit the circulation of water bearing these minerals. The decomposition of jasper and shale to serpentine rocks seems to be more the action of hydrothermal than dry heat.

In places the spaces between the fragments of shales and serpentine rocks are filled with quartz carrying a notable amount of copper pyrites and a small amount of gold and silver. By an examination of the sectional views and sketch it will be seen that the northern side of the metamorphic rocks cuts the

strike of the unaltered rocks diagonally, and that on the south side they run parallel with the strata of the unaltered rocks, sandstone being in contact with the serpentinic rocks.

A sectional view shows that the unaltered rocks on the south are part of the same strata as the unaltered rocks lying on the north of the metamorphic rocks. The unconformity of the metamorphic rocks with the sandstones and shales on the north, and their conformity with the sandstones and shales on the south, taken with other phenomena described in this article, clearly demonstrate the fact that these unaltered rocks were not deposited on the altered rocks after they were metamorphosed. The unaltered shale underlying a sandstone is of great thickness, whereas at a point half a mile east of this sectional view the metamorphic rock is nearly in contact with the same sand stratum.

Northeast of the metamorphic rocks are alternating beds of shale and sandstone. The shales are highly silicated. Silica dissolved in hot waters slowly ascended through the unaltered rocks lying north of the metamorphic rocks. The metamorphic rocks acted as a dam for its retention, and as these hot waters cooled they were incapable of holding the same amount of silica in solution as when hot; therefore, silica was deposited in the interspaces of the porous rocks. When silicious waters flow upward through a formation the rocks are silicated, and when the water flowed or flows downward through a formation the rocks are leached.

There are several reasons why this occurs. When waters flow upward their flow is generally very slow; when coming from the depths of the earth the waters are generally hot, gradually cooling as they approach the surface, and as they cool silica is deposited.

Silica is soluble in cold water. Under pressure and heat the solvent power of water is greatly increased. Upon the relief of the pressure or the cooling of the hot silicated water, silica is deposited. A solution of silicate of soda, when undisturbed for a year or more, will deposit silica; if frequently disturbed, no such deposition takes place. The deposition of silica from such a solution is quickened by the presence of carbonic acid. Petrified wood is often found in rocks that are not silicated. This is owing to the fact that the capillary tubes in the wood are much smaller than the interspaces in

the circumjacent rock. Water filters through the wood and these rocks more or less quickly in proportion to their permeability; consequently, circulation of fluids is slower in the wood than in the adjoining rocks.

Rapid percolation of silicious waters through a rock prevents the deposition of silica. Shales and other substances containing small pores are very frequently silicated, whereas the adjoining sandstones or coarse substances are still porous. The greater porosity of the sandstones and other coarse-grained substances permit a too rapid flow of the silicious water, and silica is not deposited; whereas, since the percolation of silicious water in the fine shale or other fine-grained substances is extremely slow, silica is deposited. When these cherty shales are black it shows that bitumen was ascending with the silicious waters at the time they were silicated. After being silicated they do not split along the plane of original deposition. Their hardness is 7. Their black color is destroyed by fire, showing that their color is due either to a bituminous or a carbonaceous substance. It is in all probability the former, as carbonaceous matter does not, whereas bituminous matter does, accompany the flow of silicious waters. In many places these blackened and silicated shales adjoin cracks and seams, through which mineral water accompanying bitumen is ascending.

Zaca Peak owes its prominence to the protection of a crown of cherty shale; in fact, the preservation of this mountain range is owing to its silicification, which must have occurred before it rose above permanent water; whereas, several thousand feet of sediments lying to the southwest of the same have been denuded in consequence of being leached and broken.

Silicated shales and sandstones are not easily eroded, and suffer but slight decomposition through the action of the weather. The sandstone is not indurated to the same extent as the shale. The face of the shales is flatter than the face of the sandstones; the sandstones are nearly vertical. Frequently these cherty shales contain many small faults and cracks, the character of which shows that they were made while the shale was in a semiplastic condition. They have been silicated subsequent to their faulting and cracking, clearly showing that shales were silicated after the formation had been greatly disturbed. The alteration of these white shales has been partly

caused by baking, through the heat of adjacent metamorphic rocks. Joints and seams in the shales and spaces in the sandstones are colored red with the oxide of iron.

In part of the bituminized sands lenticular pieces of shale are found converted into chert, and fossil shells have been removed. These silicated lenticular pieces of shale were silicated after being water-worn, as their exteriors have all the appearances of shale. If they had been changed to chert before being water-worn, they would have had a polished surface. They show the laminæ of deposition, but do not split along them.

The insoluble silica in the pieces of shale consists of fine quartz sand which composed the original shale, whereas the soluble silica was deposited in the pores of the shale from infiltrating water. These fragments of shale were silicified before the interspaces of the sand were filled with bitumen, as the circulation of water ceased after the appearance of the bitumen. For the same reason fossil shells must also have been leached from the sands before they were filled with bitumen. Therefore, these sands were bituminized after their deposition, and must have been bituminized before they were tilted to the high angles which they now occupy, and before the metamorphic rocks came in contact with them.

The bituminized sand near Zaca Creek contains at least ten million barrels of maltha. Eight barrels of ordinary petroleum are required to make one barrel of maltha. As the interspaces of the bituminous sand are filled with maltha, a space ten times as large as the present bituminous deposit was required to accommodate eighty million barrels of petroleum before it was changed to maltha. The apex of the anticline lying above the metamorphic rock, when the curvature of the rocks was slight, must have been the storage room for this vast amount of petroleum. When the strata of this anticline containing the petroleum slowly rose above permanent water, and owing to the fact that the anticline rose to a higher altitude in the east than in the west, the oil flowed down the porous strata towards the west, and during the flow was evaporated, forming maltha, which finally reached its present resting place. During this migration of the oil, besides the amount dissipated by evaporation, a vast amount must have been

carried away by percolating waters or drained from the porous strata and was lost.

In 1864 a multitude of fish were asphyxiated in the Pacific Ocean and came ashore between Monterey and Ventura in large quantities. Many were dead and others were barely alive. This was probably occasioned by the ocean waters being charged with sulphuretted hydrogen or carbonic acid. These mephitic gases emanated from metamorphic action beneath the ocean, ocean currents and migratory habits of the fish submerging them in the deadly waters. In 1899 the fish were killed in Zaca Lake by sulphuretted hydrogen, the presence of sulphuretted hydrogen being evidenced by the whitish state of the water, caused by the liberated sulphur. The Indians had a number of superstitions regarding this lake, which were probably occasioned by former phenomena which appeared supernatural to them.

Conclusions.—Black or dark-colored cherty shales and sandstones show that bitumen accompanied the silicious waters while these rocks were being silicated. Light-colored cherty shales and sandstones show the absence of bitumen during their silicification. These cherty shales and sandstones indicate either that silicious waters have cooled while ascending towards the surface, or that the circulation of the silicious water, generally upwards through them, has been very slow. Both these flows of water would have a tendency to remove petroleum from a formation if any had existed therein. If bitumen deposits exist in a formation the leached shales and sandstones usually overlie them, although white leached shales and sandstones may exist where there is no bitumen.

PROSPECTING FOR PETROLEUM.

Surface indications of the presence of petroleum consist of unaltered rocks, white-leached shales and sandstones, shales burnt to redness, fumaroles, mineral springs and the residue from mineral springs, such as selenite, etc., subsidences, natural gas, springs of petroleum oil and maltha, porous rocks saturated with bitumen, cracks in shale and other rocks filled or partly filled with bitumen, black silicified shales.

It would seem like supererogation to say that petroleum oil is not found in any notable quantity in metamorphic rocks, and

if found at all that it is a secondary deposit. One may as well expect to find accumulations of petroleum in a limekiln as in metamorphic rocks, yet notwithstanding this fact, which one would think would be patent to every person, wells for oil have been drilled in granite. The prospector should confine his attention to unaltered rocks.

The color of the bitumens, when they exist near the surface of the earth, is black, bluish black, and brown and dirty brown. The bitumen can be determined from coal, vegetable deposits, iron, manganese, and other minerals that closely resemble them, by the following tests: By its bituminous odor and taste; by melting in the flame of a match or candle with a bituminous odor (iron and manganese do not fuse, and coal and vegetable matter burn without fusion); by dissolving in bisulphide of carbon, chloroform, and turpentine.

It would be well, in prospecting for oil, to carry a small bottle of one of these solvents and another small bottle in which the substance to be determined is placed in a comminuted form and agitated. If a brown or black solution is formed, the substance under examination is bitumen. Iron, manganese, coal, and vegetable matter do not dissolve in these solvents.

All streams, pools, and other bodies of water should be carefully inspected. If oil is present it will float on the surface, showing prismatic colors. Compounds of iron floating on the surface of water frequently show these iridescent colors. Whether this scum is oil or an iron compound can be determined by stirring the surface of the water with a circular motion. If iron, the scum will break into irregular fragments, and if oil it will form bands of color. In other words, the iron compound seems to act and break like a solid, whereas the oily scum acts like a liquid.

Frequently gases are seen to ascend from the bottom of streams and pools of water. In the bed of La Brea Creek, upon the Sisquoc Rancho, Santa Barbara County, gases rise from the bottom of the creek for a distance exceeding one mile, which can be lit upon the surface of the water and burn with a luminous flame. This occurs in many other places in California.

Carburetted hydrogen, or natural gas, is a far greater indication of the presence of the bitumens than is sulphuretted

porous sand is reached, or when the outcrop is porous sand, it can be presumed that the bitumens reached the surface through the sand. Especially is this liable to be true if the sandstones stand at a high angle with the horizon.

Subsidences are indicative of the presence of petroleum, but if any oil is found in them it will be viscous and heavy, the fractured condition of the earth in the subsidence permitting the escape of the volatile parts of the oil. This is also true of burned shales, and if any petroleum exists in these shales it would be a secondary deposit, having entered the shales after they were burned. Petroleum vapor in all probability assisted in the burning of these shales.

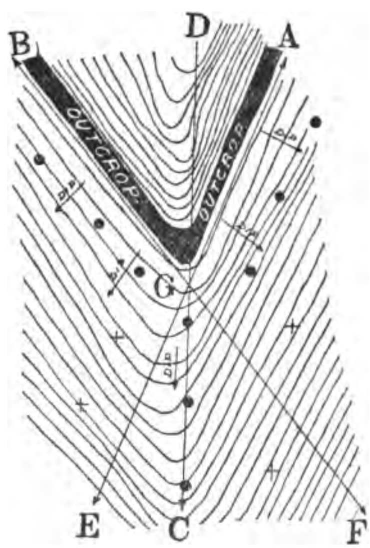


FIG. 27.

As mineral waters always accompany the bitumens, mineral springs and the evidences of former mineral springs are to a limited extent evidence of the accumulations of the bitumens. Selenite, travertine, infusorial earth, and a number of other mineral deposits are evidences of former mineral springs. When bitumens exist in a formation they are more often than otherwise overlaid with white leached shales and sandstones; therefore, these rocks are an indication of the bitumens to a certain extent, and, owing to their conspicuous color, can be seen from a long distance.

In Fig. 27 there is represented a horizontal plane showing outcrop of a sand-bearing petroleum. The strike of an anticline should not be confused with the strike of the strata or outcrop. The strike of an anticline is its axis plane, shown by C D on this diagram. The strike of the strata or outcrop is shown by the lines G B and G A. The outcrop may be followed in the directions shown by the arrows A and B, and in some instances for a long distance, with a liability of discovering oil in the depths of the dip of the oil strata, even when bitumens are not seen upon the surface.

So can the apex of the anticline D C be followed in the direction of the arrow C, and in some instances for many miles, with a reasonable expectancy of getting oil by drilling wells, even if no bitumens are to be seen upon the surface; but it would be an absurdity to follow the direction of the outcrop G B and G A in the direction of E or F, for the farther one goes in these directions the farther he will be getting away from the petroliferous strata.

Therefore, outcrops and anticlines can be followed from outside property into the property being examined, and the structure be considered sufficiently well demonstrated so as to justify a person in drilling a well for oil, even if bitumens were absent from the surface of the land upon which the well is to be drilled and the exposures of the strata are but slight. The strike of the anticlines and outcrops can be determined by a pocket compass.

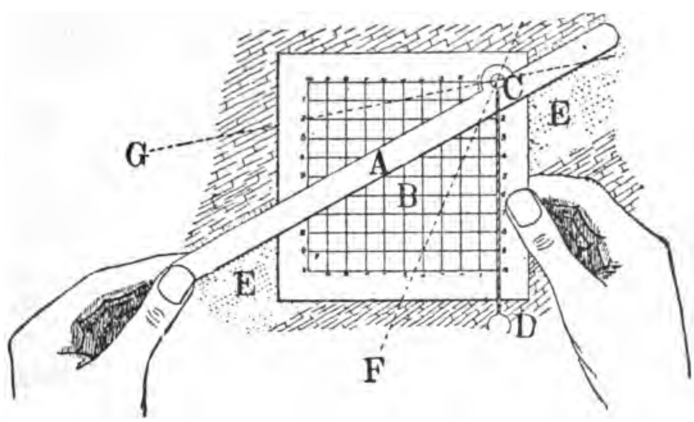


FIG. 28.

Fig. 28 shows a clinometer, to be employed for the determination of the dip of rock strata or the slopes of hillsides. It can be readily made out of stiff cardboard. B is a piece of stiff cardboard upon which is traced the squares and numbers in the manner shown in the figure. A is a piece of cardboard cut in the shape as shown in diagram. These two pieces are hinged together with the rivet C, this hinge permitting one piece of cardboard to move upon the other. Care should be taken to see that the upper edge of the cardboard A passes through the center of the rivet, and also that the center of the rivet C is on the upper and right-hand corner of the squares B.

A plumbob D is suspended from the rivet C, which helps the observer to keep the vertical lines of the clinometer vertical.

When an observation is made the clinometer is held in the manner shown in Fig. 28, and while the cardboard B is held vertical, which is determined by the plumbob C, A is moved upon B until its dip agrees with the strata E E (in Figs. 28 and 29), or other strata under examination. Considering that each square represents ten feet square, the readings of the clinometer would be as follows: First, with the upper edge of A on line G; second, with the upper edge of A as represented; third, with the upper edge of A on line F.

	Vertical.	Horizontal.
1	20 feet	100 feet
2	56 "	100 "
3	100 "	45 "

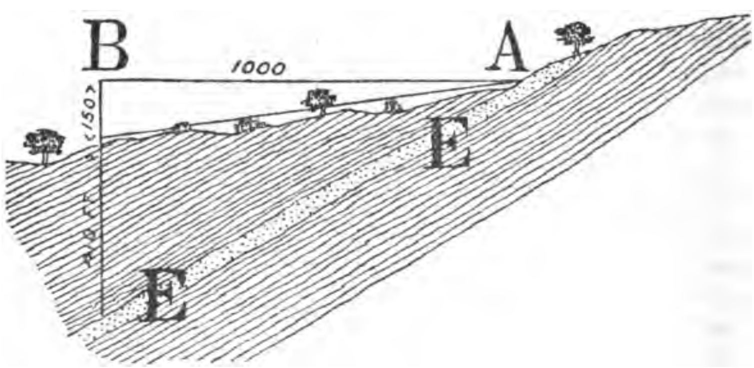


FIG. 29.

After the observations are taken in the field the clinometer can be used to draught the sectional views.

One use of the clinometer is shown in Fig. 29. With the clinometer the bituminous sand stratum E E is determined at its outcrop A, and found to be equal to 1,000 feet horizontal and 560 feet vertical, and the slope of the land is found to be 1,000 feet horizontal to 150 feet vertical. The vertical depth of the slope being deducted from the vertical depth of the bituminous stratum below B, shows that a well to reach the bituminous stratum at B, 1,000 feet from A, would have to be drilled to a depth of 410 feet. When grown familiar with the operation of this clinometer, it can be used for many purposes and different examinations.

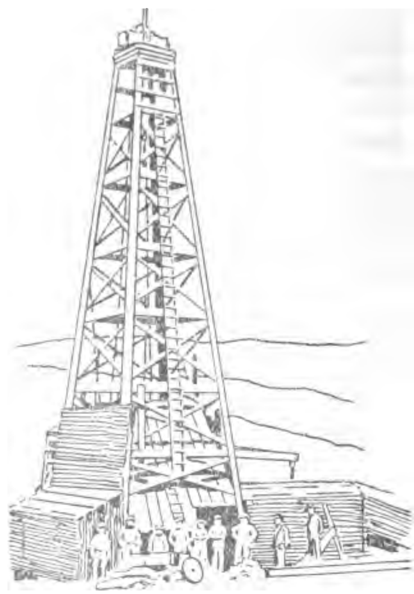
If indications of the presence of bitumen are sufficient to justify it, a topographical map of the presumed oil territory should be made before making a cross-section of the rock structure. If a person is incapable of making a topographical map of the territory, he certainly has not the capacity of making sectional views of the same showing the structure, the latter operation being much more difficult and largely dependent upon the former.

All indications should be closely examined and thoroughly studied. Even with the greatest attention given to these details before selecting a place to drill a well, there is danger that the lower parts of the bituminous strata encountered in the well may contain water in place of gas and oil; or may be calcified or silicified instead of being bituminized; or that water has entered the outcrop of the strata at higher altitudes and ascended through the formation, floating the oil to the surface or carrying the same to the other dip of the anticline.

Theory and observations cannot be perfect, but are far better than guessing.

Some of the Fallacies.—Clairvoyants can see as far into a millstone as any one, but no farther. Divining rods were first used to detect perjurers, but since liars have commenced to use them they have lost their virtue and are of no value. Accumulations of fossil shells and bones are not indices to deposits of bitumen; vast masses of shells and bones exist where there is no petroleum. The same compass-bearing is not applicable to all deposits of oil. Hardly any two have the same strike, and the strike is frequently curved. The age of the unaltered rocks bears no relation to the accumulations of bitumen.

The mere geological age of the unaltered shales and sandstones in California does not inform us of the nature of these rocks; nor can we, on the other hand, from their petrographic character, arrive at the geological age of these rocks. No kind of unaltered shale or sandstone is restricted to any particular period.



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THE MAY ROCK, MARIPOSA COUNTY.

CROPPINGS OF THE EAGLE-SHAWMUT MINE, TUOLUMNE COUNTY.

CALIFORNIA STATE MINING BUREAU.

A. S. COOPER, STATE MINERALOGIST.

BULLETIN No. 18. San Francisco, October, 1900.

THE

Mother Lode Region of California.

By W. H. STORMS, E.M.

Published under the Direction of HENRY T. GAGE, Governor of the State of California.

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1900.

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SAN FRANCISCO, CAL., September 30, 1900.

To His Excellency HENRY T. GAGE, *Governor of the State of California*;
THE HONORABLE THE BOARD OF TRUSTEES OF THE CALIFORNIA STATE MINING BUREAU; *and* HON. A. S. COOPER, *State Mineralogist.*

GENTLEMEN: I have the honor to submit herewith the report of my investigation of the mines of the Gold Belt in El Dorado, Amador, Calaveras, Tuolumne, and Mariposa Counties during the spring and summer of 1900. I regret that the necessity of visiting some of the northern counties of the State during June and July made it impossible to complete the work during the season, but, as it is a field of active operation, the coming year will find development further advanced, and at that time the investigation may be continued with more satisfactory results than would have been obtained had the work been done the past season. Very few other than operating mines were visited, and of these the description in this bulletin is limited to the most important ones, the others appearing in a general report which shortly follows this bulletin.

I find among the more progressive superintendents and mine managers a disposition to experiment with a view to improving mining methods and to decreasing the expense of treating ore, and as a result we find not a few innovations which in most cases will be adopted in general practice, with such further improvements as additional experience may suggest.

It affords me great pleasure to state that the mine owners, managers, and superintendents, almost without exception, spared neither time nor trouble in affording every facility for investigation of the mines under their direction, which made the task not only light, but pleasant.

I am, yours respectfully,

W. H. STORMS.

THE MOTHER LODE REGION OF CALIFORNIA.

By W. H. STORMS, E.M.

The California Gold Belt has furnished a most interesting field for geological research ever since its discovery in 1849. It has received the attention of many geologists, and a great deal has already been published concerning it. Among the most noted and valuable of these contributions to our knowledge of the Gold Belt are the early writings of Dr. Rossiter W. Raymond and Ross E. Browne, and more recently those of H. W. Fairbanks and Ross Browne, and the exhaustive maps and reports of the United States Geological Survey. The various reports of the State Mining Bureau have also furnished a large amount of valuable technical and statistical information on the subject.

In consideration of the very large amount of descriptive matter already published concerning the mines of the Gold Belt, or Mother Lode, it was with the feeling that the subject was worn somewhat threadbare that the writer undertook the re-investigation of this important mining field in January, 1900.

Since the publication of the XIIIth report of the State Mineralogist in 1896, no publication has been issued by the State regarding the progress of work in the counties along the Gold Belt, though this period has been one of unusual activity and progress and also of innovation in these mines. Old methods have in many cases given place to more modern ideas, and still more radical changes may be anticipated in the near future.

An era of deep mining has commenced which can only be carried to the greatest success by the adoption of modern mining methods and improved machinery, together with a closer attention to the economical treatment of the ores. Already it has been shown that mines which were worked in former years under disadvantages and at an expense considerably above that now necessary to accomplish given results, after years of idleness, upon being reopened and equipped with modern machinery, can again be made to yield a handsome profit, where formerly some of them were worked at a loss.

This has been made possible by the reduced cost of labor in later years; by the superior efficiency of nitro powders over the black blast-

ing powders used formerly in all mining operations in this State; by better and cheaper mining supplies of all kinds; and in no small degree, by improved hoisting, pumping, and milling machinery, and to some extent also by improved mining methods.

There is little doubt that the marked mechanical success attending very deep mining elsewhere, notably in the Lake Superior copper mines and in the gold mines of South Africa, has proven a great incentive to the miners of California to emulate, in a measure at least, these splendid efforts, and we now find large vertical shafts being sunk to a depth far exceeding anything heretofore attempted in California mines.

There are mines in Amador and Nevada Counties now operating to a depth of 2500 feet or more through old inclined shafts, usually sunk to conform to the dip of the vein, or approximating it, and there are numerous mines in several mining counties where inclined shafts are down 1500 to 2000 feet. The managers of these properties realize the importance of having shafts sunk at a uniform angle—whether vertical or inclined—thoroughly equipped and provided with the best hoisting machinery in order to reduce the cost of mining to a minimum, for in nearly all of the large mines it is known that there are immense bodies of low-grade ore, too poor to pay when worked by old methods, but which would afford a good profit if mined by modern methods and with well-equipped shafts and machinery of proper construction. This matter will be more fully discussed under the title of "Methods of Mining."

The introduction of extensive slimes plants, and the successful operation of the cyanide process in its various forms, have also contributed in a measure to increased financial success, and electric plants have also been installed at several points for the distribution of power to mines along the Gold Belt. These installations are said to be successful financially as well as mechanically. Transmission of power through the medium of compressed air, though not an innovation, is more extensively employed than formerly.

GENERAL GEOLOGY OF THE GOLD BELT.

Owing to the extremely complicated structural geology of the California Gold Belt, positive assertions as to the relative age of the intrusive rocks which so commonly occur throughout its length are generally unsafe, but in a general way it may be stated that, upon rocks of an uncertain but very great age, possibly Archæan, there was laid down in Palæozoic time a deep series of sediments consisting of mud, sand, finely comminuted calcareous fragments, calcareous ooze, etc. Following this there was evidently a long period of volcanic activity, during which there was accumulated a vast quantity of basic rocks, chiefly diorite and diabase, and basic tuffs and breccias. These rocks are mineralogically closely allied to the andesites, and are called the old andesites by the United States Geological Survey. The underlying formations, together with the tuffs, were consolidated into rock; the mud being transformed into shale, and by further process of metamorphism, into slate, the sand becoming quartzite, and the calcareous material, limestone.

There were evidently successive periods of elevation and subsidence also, resulting in the formation of extensive beds of conglomerate along the shore lines. During the Jurassic age there was deposited upon these older formations a stratum of fragmentary material consisting of fine silt and sand, forming eventually thick beds of shale and sandstone.

During a portion of this period volcanic activity was again pronounced, particularly about the close of the period, during which there was again accumulated a large amount of diabase tuffs and breccias. In some localities the mud deposits and the tuffs are found interbedded, showing that the volcanic outbursts were intermittent. In some cases a sandstone is found wholly made up of diabase material, and this is probably the result of the disintegration of some previously erupted material, which was carried down from an elevated ridge and deposited in the bed of the sea. These sediments have subsequently been uplifted, folded, crushed, and faulted. The dynamic forces were still at work, and large dike-like masses of diabase, diorite, serpentine, and other intrusive rocks were thrust from below into the complex of older rocks.

The Palæozoic rocks, owing to their large development in Calaveras County, have been named the Calaveras formation, and the later deposits of Jurassic age have been called the Mariposa beds (as this formation is most extensively exposed in Mariposa County), and it is in more or less close association with these beds that the so-called Mother Lode of California occurs.

Lying to the eastward of the above described formations is found a broad expanse of intrusive rock, which, owing to its peculiar mineral-

ogical character, has been named grano-diorite. At numerous points along the contact of the grano-diorite with the formations heretofore mentioned there is found abundant evidence that the grano-diorite was intruded later than the greenstones, and it is also later than the Mariposa beds. There is some reason to believe that the grano-diorite is as late as the Cretaceous.

The Mariposa beds appear generally to occupy a position along the trough of a synclinal fold, the Calaveras formation being found both to the eastward and westward of the Mariposa beds. The occurrence of the diabase tuffs and the intrusion of great masses of basic dike rock (diabase and diorite) have rendered the positions of the Mariposa beds and the Calaveras formation very irregular and often extremely puzzling, as the distribution of the tuffs, breccias, and intruded dikes is most erratic. It is more than probable that a cross-section taken every half, or even every quarter mile along the Gold Belt, would show an entirely different structural condition.

The Schists and Metamorphic Rocks.—The tremendous compressive stress to which these rocks have been subjected since their uplift, has resulted in the formation of a series of highly crystalline metamorphic rocks—the mud being altered into slates, the sandstones changed to quartzite, and not infrequently the limestones are found altered to marble. The greenstones have likewise been changed over broad areas. The pressure and movement accompanying it have resulted in many cases in a complete obliteration of the original character of the normal rocks, and in place of the crystalline granular greenstones we find schists and slates (the amphibolite schist of the United States Geological Survey). Throughout the entire length of the Gold Belt are found greenstones of greatly varying texture (chiefly diabase), which have suffered little or no alteration.

These masses of greenstone are from a few feet to several hundred feet in width, and it seems not improbable that they were mostly intruded since the formation of the schists. In some instances this is positively known to be the case, as they are found cutting the schists in strike and dip. In some of the gold mines these greenstone dikes may also be clearly seen to be more recent than the inclosing rocks, and occasionally they are found intersecting the quartz veins.

Instances may be observed, however, where only portions of certain massive formations are schistose, and this can only be attributed to the local effect of the dynamic forces similar in character to those which produced the original metamorphism of the older formations. The general features of the schistose greenstones (both massive and tufaceous) occurring in California are so similar physically to those of the Marquette and Menominee regions of Michigan that there seems no room to

doubt that in each case similar causes operated to produce like effects. The Michigan region has been studied with great care by several of the best geologists of America. Those interesting rocks and the manner of their formation have been fully described by G. H. Williams, and a few extracts are taken from his excellent contribution to this important subject, the dynamic metamorphism of eruptive rocks,* for the reason that they apply so perfectly to the conditions found in California along the Gold Belt, and I have not the slightest doubt that greenstone schists, wherever found, whether as the result of the alteration of massive greenstone tuffs or of fragmental rocks (sandstones), derived from the degradation of older greenstones, are the direct result of the causes ascribed by Mr. Williams as having produced the schists of the Michigan region.

In referring to the value of the microscope in the study of metamorphism of rocks, Mr. Williams says:

> The most important problems presented by an unaltered massive or igneous rock relate to (1) its chemical composition, and (2) to the conditions under which it was formed. The composition expresses itself in a general way, in the nature of the component minerals, while physical conditions attendant upon the formation of the rock may be traced in its structure. Each of these has therefore been, in turn, the particular object aimed at during the first two periods of petrographical research.
>
> But if petrography were able to solve satisfactorily all the problems presented by the unaltered massive rocks, it would even then be prepared only to commence its most difficult and most important mission. Rocks are in reality far from being dead, inert, stationary masses, which they appear to the ordinary observer. The fascinating study of chemical geology, especially when aided by the microscope, shows them to be in a state of almost constant change. It is true that some of the oldest rocks seem to have suffered hardly any alteration since they were first formed, but most of them are ever-active laboratories where old products are being pulled to pieces and new ones built up. The tracing-out of such changes is an important aim of petrography in its present stage.

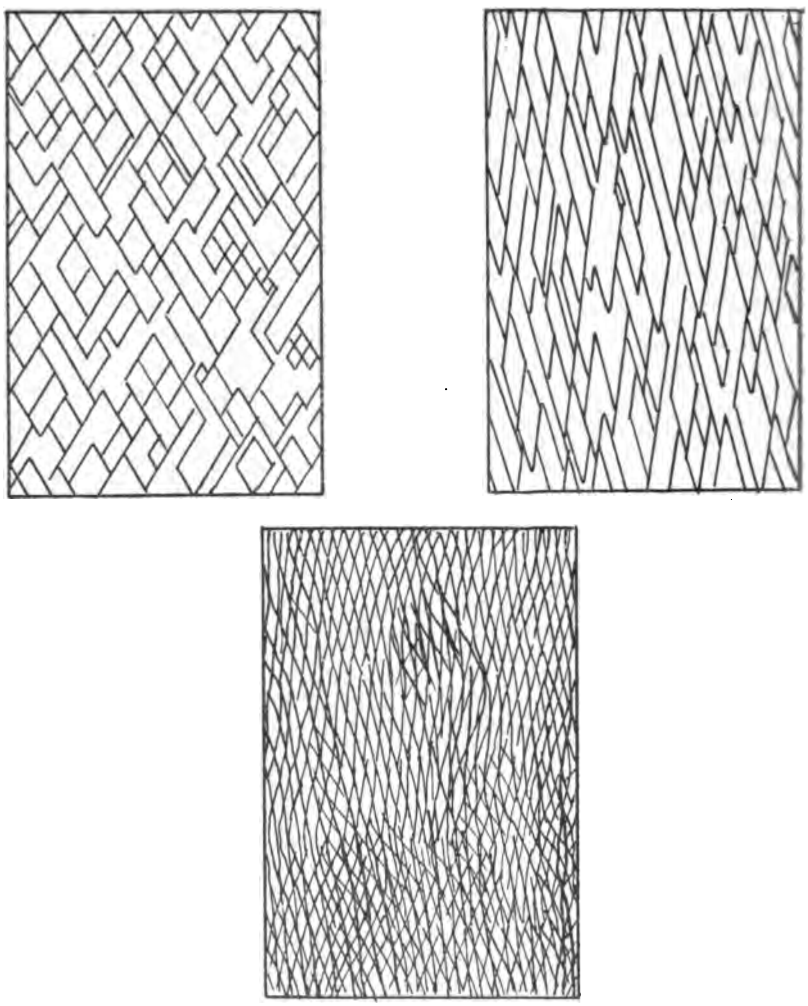
In the study of the structural geology of the California Gold Belt, it was found necessary to employ the microscope, and the conclusions reached in this study are identical with those submitted by Mr. Williams. Upon his study in the Michigan area, continuing, he says:

> There are two distinct kinds of alterations which take place in a solid rock mass, dependent, of course, on the nature of the changed physical conditions. These are:
>
> (1) Metamorphism; or the passage, under circumstances of high temperature or pressure, or both, of less crystalline into more crystalline compounds; or the change of minerals into others not less crystalline or insoluble than themselves.
>
> (2) Decomposition or weathering; the passage, under ordinary atmospheric conditions, of crystalline rock constituents into compounds less crystalline and more soluble than themselves. This is accomplished generally by hydration or carbonization.
>
> Both of these processes are frequently seen to have gone on in succession in the same rock mass, the latter more or less completely effacing the effects of the former. While distinct, both processes agree in being atomic and molecular rearrangements in a solid mass, necessitated by some change in external conditions. The differences in these conditions, however, produce widely different results; and all of these again are essentially different from those produced by the solidification of a liquid magma.
>
> The student of the crystalline rocks can distinguish, in a general way, four classes of

*Bulletin No. 62, United States Geological Survey. "The Greenstone Schist area of the Menominee and Marquette regions of Michigan."

constituent minerals, and this is true in spite of the fact that the same species may be represented in two or more of these classes:

(1) Original minerals of the acid rocks, formed by the solidification of a magma in a state of aqueo-igneous fusion or by the aid of mineralizers; e. g., quartz, orthoclase, mica, zircon, etc.



DIAGRAMS illustrating the transition from jointing to schistose structures in the greenstones.

FIG. 1.

(2) Original minerals of the basic rocks, formed from a state of dry fusion; e. g., plagioclase, augite, olivine, etc.

(3) Metamorphic minerals, formed as above explained, from originals; e. g., hornblende, albite, biotite, zoisite, garnet, staurolite, andalusite, etc.

(4) Decomposition minerals; e. g., chlorite, quartz, carbonates, hydroxides, etc. * *

Rocks may be altered by simple pressure, but the accumulated strains which are generated within them are relieved and adjusted by overcoming the force of cohesion along certain planes. Here there will be a shearing motion of greater or less extent, and a consequent crushing of the rock. The rent is soon healed by the crystallization of new compounds which cement the crushed fragments, and in this way a schistose band, of width varying with the intensity of the force, may be developed in the midst of an otherwise solid and massive rock; or a number of such bands may be formed parallel to one another and together imparting to the rock the appearance of a foliated or even a banded schist.

Conclusive proof of this process might be difficult to discover without the aid of a microscope, but this instrument is happily able to afford sufficient evidence to overcome all doubt. * * *

The first step toward the formation of a schistose structure in Twin Falls greenstones (and this is hardly ever absent) is the division of the massive rock by two systems of joints, which stand about perpendicular to the surface and intersect at a varying but acute angle. These joint systems divide the mass into diamond-shaped or rhomboidal prisms, the cross-sections of which are well displayed upon the frequent smoothly glaciated surfaces of the rock. The appearance of such a surface is diagrammatically represented in Fig. 1.

As we approach the schistose band in the massive rock these interlacing rhombs become lengthened out more and more by an approximation to parallelism between the two systems of joint planes.

These elongated prisms finally become very much extended lenses, which interlock and produce a well-developed, wavy, or even parallel schistose structure. The almost slaty rocks thus produced, especially as seen at Lower Twin Falls, have a tendency to break, not so much along a definite plane, as parallel to a line—i. e., the direction, normal to the surface, parallel to which the original joint planes ran. It is difficult to obtain well-shaped hand-specimens of these rocks, but narrow rhombic prisms of almost any angle are easily procured. There is an almost equal tendency to cleave along any plane which is parallel to the longest axis of these prisms.

If the prisms due to the original joint planes were subjected to a lateral pressure which developed in them a cleavage that successively approached more and more nearly to the long axis as the prism was lengthened, this peculiar tendency to separate along a line rather than along a plane is precisely the structure which we might suppose would result.

The strike of these schistose bands follows the direction which bisects the acute angle of the rhombic prisms. This is for the most part from S. 70° to 80° E.; agreeing with the prevailing strike of all the rocks in this system. There are, however, many exceptions where these schistose bands, even where near together, follow different directions; for instance, I observed in the massive though jointed rock on the Michigan side of Upper Twin Falls, two schistose chloritic bands quite near together, one having a strike N. 180° E., and the other S. 73° E., while the dip of each was nearly vertical. Such cases are easily explicable on the supposition that these bands were produced by mechanical agencies, but it is quite impossible to reconcile them with the supposition that these bands are in any way the result of sedimentation.

It is not infrequently noticed that there is a local development of schistose structure of massive rocks in the immediate neighborhood of fissures and veins. A typical instance of this character may be observed on Wood's Creek, a few hundred feet below the pumping-station, near the Bonanza Mine at Sonora, in Tuolumne County. Here a quartz vein, about twelve inches in width, traverses a hard, dark-green diorite. The walls on either side are altered for a width of three to five feet, being soft talcose or chloritic schist near the vein, and passing over by transition to the normal diorite. These occurrences are not at all uncommon, though often of local character.

In Amador and Calaveras Counties, and also to some extent in El Dorado County, I found peculiar banded schists, which have attracted the attention of many geologists. Similar banded schists occur in the Michigan area, above referred to, of which Mr. Williams speaks as follows:

The banded greenstone schists which form the prevailing rock over the northern portion of the Marquette area, have been regarded by all geologists who have ever studied them, as originally sedimentary deposits, and repeated examination of them in the field seems incapable of leading to any other conclusion. They are everywhere stratified with the greatest regularity in bands of lighter and darker shades of green. This structure is to be most advantageously seen in the woods just north of Marquette and near Lighthouse Point. Here glaciated areas of considerable extent often show a finely ribboned appearance, looking as though the sharp parallel lines had been drawn with a ruler. The alternation in the composition of the layers is so frequent and so constant and their parallelism to the east and west strike of all the rocks in this neighborhood is so exact, that no hypothesis of their originally massive character will satisfactorily account for the observed facts. * * *

On the other hand, their chemical as well as their mineralogical composition renders it impossible to separate them from the massive and highly altered greenstones (uralite diabases, etc.), with which they are most intimately associated. Their parallel banding indicates a fragmental, but their chemical and their mineral composition indicate an igneous, origin. The only satisfactory reconciliation of these opposite sets of characters is to be found in that group of rocks intermediate between sediments and lavas, known as volcanic tuffs.

In the opinion of the writer, then, the banded greenstone schists of the northern Marquette area are to be regarded as consolidated and highly metamorphosed diabase tuffs. These are intimately associated with the numerous contemporaneous flows of diabase and quartz porphyry, together with the tuffs of the latter rock; while all have been broken through by much younger dikes, both basic and acidic.

* * * * * * * * * * * *

In order to obtain a clear idea of just how these ancient and much disguised tuffs acquired their present form and apparently dual character, it will be advantageous to ascertain what is known of analogous formations of comparatively recent date. Captain C. E. Dutton's descriptions of the fragmental rocks accompanying the Tertiary eruptives of the high plateaus of Utah are well suited to this purpose. He says, in speaking of the extent of these deposits:

"Some of the most interesting lithological problems presented by the volcanic products of the high plateaus are those relating to the origin and development of what may be termed the clastic igneous rocks, or rocks apparently composed of fragmental materials of igneous or volcanic origin, but now stratified either as so-called tufaceous deposits or as conglomerates. These are exceedingly abundant in all of the great volcanic districts of the world, and often enormously voluminous.

"How those of the high plateaus would compare, in respect to magnitude, with those of other regions, I do not accurately know, but absolutely their bulk is a source of utter astonishment. They cover nearly 2000 square miles of area, and their thickness ranges from a few hundred feet to nearly 2500 feet, the average being probably more than 1200 feet. Lavas are frequently intercalated, but much more frequently no intercalary lavas are seen, and in general they seldom form any large proportion of the entire bulk when they occur in conjunction with the clastic masses."

Again, in speaking of the peculiar liability of such deposits to metamorphism, the same writer says:

"A very striking characteristic of these clastic volcanic rocks, both the tufas and the conglomerates, is their great susceptibility to metamorphism. Not only have the beds in many localities been thoroughly consolidated, but they have undergone crystallization. These tufas and conglomerates, which are of older date, and which have been buried beneath more recent accumulations to considerable depths, rarely fail to show

conspicuous traces of alteration, and in many cases have been so profoundly modified that for a considerable time there was doubt as to their true character.

"The general tendency of this process is to convert the fragmental strata into rocks having a petrographic facies and texture very closely resembling certain groups of igneous rocks. When we examine the rocks in situ, no doubt can exist for a moment that they are water-laid strata. The hand-specimens taken from the beds, which are extremely metamorphosed, might readily pass, even with close inspection, for pieces of massive eruptive rocks, were it not for the reason that the original fragments are still distinguishable, partly by slight differences in color, partly by slight differences in the degree of coarseness of texture. But the matrix has become very similar to the included fragments, holding the same kinds of crystals, and under the microscope it shows a ground-mass of the same texture and composition."

The Alteration of Other Massive Rocks.—The greenstones are not the only massive rocks which have undergone a more or less complete alteration in the region of the Gold Belt. There are two rocks in particular to which I wish to call attention. These are the calcareous rocks which constitute the great dolomitic vein, previously referred to, and a dark green, massive, extremely hard, and tough rock found at numerous places along the Gold Belt, notably in Calaveras County just east of San Andreas; near Dogtown, three miles from Angels; at Smith's Flat, west of Angels, and elsewhere. The ankerite or dolomite vein is usually distinguished by its great width and massive character, and the occurrence of more or less abundant mariposite; but in many places we find this hard, thoroughly crystalline rock has been compressed, sheared, and completely altered, passing over by gradual transition to typical soft talc schist.

A series of transition rocks of this character was obtained at the Pacific Mine, Placerville, El Dorado County, and is on exhibition in the Museum of the State Mining Bureau in San Francisco. Similar occurrences have been noted in a score of mines, from Mariposa County northward as far as Placerville, but collections from other mines have not been placed upon exhibition, because the occurrence is essentially the same in each case, and the space available in the Mining Bureau is already crowded.

Concerning the other massive rock, hand-specimens were selected from the Ford Mine at San Andreas, also from a similar occurrence at the Smyth Mine near Angels, and slides cut for microscopic study. These prove the rock to consist of a matted aggregate of minute scales of talc, with a little calcite and magnetite. The rock, although the freshest obtainable, is very evidently not in its normal condition, but is an igneous rock which has already undergone considerable change. It may have been a gabbro or some allied eruptive rock, which, by a process of compression and shearing previously described, is now found changed into a typical massive crystalline granular or schistose steatite (soapstone). Undoubtedly, the alteration of massive rocks to a schistose or slaty condition is very much more common than is generally

supposed, but unfortunately too little attention had been given in the past to these phenomena.

It has been noticed in several instances where mine workings have been extended into the steatite masses, that not infrequently the rock is found to consist of a coarsely crystalline aggregate of semi-schistose, calcareous and magnesian minerals and to greatly resemble the partly altered ankerite and dolomite found along the Central Gold Belt. Notable instances may be found in the Ford Mine at San Andreas in Calaveras County, and at the Spanish Mine near Forest Hill in Placer County. As these rocks approach so nearly the dolomite of the Central Gold Belt, they may be considered as indicating the possible origin of the dolomitic veins from basic eruptives.

THE SEVERAL DIVISIONS OF THE GOLD BELT.

Throughout the entire length of the great synclinal trough of the Gold Belt are found the gold-bearing veins which constitute the so-called Mother Lode. It seems unfortunate that the name was ever given to this portion of the Gold Belt, as it conveys to the minds of those unfamiliar with the geological structure and veins of the region, an impression of a continuous, unbroken vein. That such a condition does not exist is well known to those familiar with these mines.

There are through that portion of the State occupied by the counties extending from Mariposa on the south to the southern portion of El Dorado County on the north, at least four distinctly recognizable gold belts: That which skirts the low foothills along the Great Central Valley includes the copper deposits found at and near Green Mountain in Mariposa County, and southward in Madera County, those at Copperopolis and at Campo Seco in Calaveras County, and at Ranlett in Amador County, and also the gold mines of Salt Spring Valley in Calaveras County. It may also be considered as embracing the gold mines near Hornitos in Mariposa County, and those near Ione in Amador County.

East of this a distance of 8 or 10 miles is found the most important gold-bearing belt of the State, which has received the name of "Mother Lode." This, it seems to me, it would be well to designate as the Central Lode of the Gold Belt. It must be understood and remembered in this connection that the gold-bearing veins are nowhere absolutely continuous and unbroken for a great distance, but that the so-called lode is frequently interrupted by its absolute disappearance for considerable distances.

Lying east of the Central Lode, in Mariposa County, a distance of nearly 20 miles, and extending in a northwesterly direction, nearly

parallel with the Central Lode, and passing through Tuolumne and Calaveras Counties, is the third gold-bearing lode, which in Amador County has approached to within 6 to 10 miles of the Central Lode. This is known as the East Lode, and embraces many interesting and important mines.

Still farther eastward lies at least one mineral belt which has been opened at several points, but of which comparatively little is known as yet. This might properly be named the Sierra Lode.

It is the intention to fully investigate this important field in the future, as it is one of great promise. The veins are large, and carry sulphides of iron, lead, zinc, and copper, and also gold and silver.

The Central Gold Belt.—It is with the Central Gold Belt we have chiefly to deal in this Bulletin, as lack of time precluded a thorough investigation the past season of the entire region comprising the Gold Belt.

For years, in fact since its early history, the clay slates of the Mariposa beds have been considered an absolutely essential feature and accompaniment of the important gold mines of the Central Gold Belt. The veins have been referred to as "contact veins," and in many sections the immediate contact, or close proximity, of the Mariposa clay slates has been deemed indispensable to pay rock.

Such, however, is apparently not the case in Amador County, where are situated the deepest and most productive mines. While it is possible that some of these mines are confined wholly to the Mariposa clay slates, or occur at contact of the Mariposa clay slates and massive greenstones, or the amphibolite schists resulting from their alteration, if such be the case the instance is unknown to the writer, for without exception, the large number of accessible mines prove that the Mariposa *clay* slates form really no important feature as related to ore deposition, while thus far in Amador County, south of Plymouth, all development confined to the typical clay slates of the Mariposa beds has proven the fissures in that formation valueless, and these developments reach many thousands of feet of shafts and drifts.

The fissures in which the ore deposits occur along the Central Lode, with no exception, so far as the writer is aware, cut the dip and usually, also, the strike of the inclosing rocks. The dip of the slaty and schistose formations is uniformly to the eastward, though at greatly varying angles, but usually between 50 and 80 degrees, while the dip of the vein fissures is always somewhat less in approximately the same direction.

In the mines of Amador County are found a peculiar black slaty rock, often approaching closely in physical appearance the clay slates of the Mariposa beds. They may usually be readily distinguished by a peculiar pitted appearance. This feature ranges from rather coarse,

thickly scattered, knotty granules, to the fine dots resembling pin pricks—the finer grained and the more slaty in structure the rock, the finer are the pits.

For years these rocks have not been distinguished from the black clay slates of the Mariposa beds, but the writer noticing that this peculiar slaty rock was of persistent occurrence with the most important ore-bodies of Amador County, determined to ascertain if possible what, if any, difference there was between these pitted slates and the smooth, satin-like slates of the Mariposa beds. With this object in view, several series of rocks were collected at various mines, showing complete transition from a massive or slightly schistose rock to a perfect black slaty rock, the specimen always showing the pits as above described, and being obtained from certain cross-cuts where the transition was evident.

These rocks were placed in the hands of H. W. Fairbanks, of Berkeley, who prepared slides and carefully studied them with the aid of the petrographical microscope. This investigation resulted in proving that these peculiar slates and schists were the result of the shearing and alteration of tuffs (evidently diabase), and that the rock was originally of fragmentary origin, though made up of diabase material (augite, plagioclase, etc.). Their character is rendered perfectly evident under the microscope, and the change from one phase of alteration to the next may be clearly traced in the several rock sections.

CLASSIFICATION AND DESCRIPTION OF ROCKS

Collected by W. H. Storms along Central Gold Belt.

Determinations made by H. W. Fairbanks, A.B.

Nos. 1 to 9, inclusive, From cross-cut 900-level, Keystone Mine, Amador County.
No. 10. From tunnel east of Keystone Mine, Amador County.
No. 11. From tunnel east of Keystone Mine, Amador County.
No. 12. From west wall of Oneida Mine, Amador County.
No. 13. From west wall of Oneida Mine, Amador County.
No. 14. From east shaft of Kennedy Mine, Jackson, Amador County.
No. 15. From east shaft of Kennedy Mine, Jackson, 900-level, Amador County.
No. 16. From hanging-wall of Bunker Hill Mine, Amador County.
No. 17. From Baliol Mine, Sutter Creek, Amador County.
No. 18. From west wall of Argonaut Mine, Amador County.
No. 19. From Carson Creek, Calaveras County.
No. 20. From dike in Copperopolis Mine, Calaveras County.
No. 21. From dike in Commodore Mine, San Andreas, Calaveras County.
No. 22. From Ford Mine, San Andreas, Calaveras County.
No. 23. From Ford Mine, San Andreas, Calaveras County.
No. 24. From Smyth Mine, Angels, Calaveras County.
No. 25. From Smyth Mine, Angels, Calaveras County.
No. 26. From Pocahontas Mine, Logtown, El Dorado County.
No. 27. From German Mine, El Dorado County.
No. 28. From German Mine, El Dorado County.
No. 29. From German Mine, El Dorado County.
No. 30. From hill north of Church-Union Mine, El Dorado County.
No. 31. From hill north of Church-Union Mine, El Dorado County.
No. 32. From hill north of Church-Union Mine, El Dorado County.
No. 33. From hill north of Church-Union Mine, El Dorado County.

Nos. 1 to 9, inclusive, are from the 900-foot level of the Keystone. Some of these have been supposed to be dikes, but Mr. Storms is unable to tell from the section given where the igneous rock ends and the supposed slate begins. A microscopic study of these rocks shows that in all probability they are all of sedimentary origin, a series of tuffs and slate, the tuffs being fragmental greenstones or diabases.

No. 1. This rock to the unaided eye has every appearance of being a dike. Porphyritic crystals of augite are embedded in a fine green matrix. Under the microscope this rock has the appearance of being a tuff. The constituents are badly decomposed crystals of augite and cloudy masses of feldspar in a finely granular base. Granular magnetite is present.

No. 2. To the eye this rock clearly betrays its tufaceous character. Its components are arranged in irregular layers. Under the microscope the tufaceous character is also seen. Augite crystals, granular magnetite, and cloudy tabular areas make up the rock. A large part of the matter of the rock is indeterminable, but there is no doubt that it is a diabase tuff.

No. 3. In the hand-specimen, this rock shows its clastic origin in the alternating layers of greenish and argillaceous material. The green is probably tufaceous, and the black of the same composition as the slates. Both show signs of metamorphism in the presence of a pitted surface caused by little crystals. The exact nature of these could not be determined, but in all these slates they are characteristic of metamorphic action. Under the microscope this rock does not show clearly its origin. It might be either a sedimentary rock or an altered igneous one. It is made up of ragged, clear, and cloudy areas. A green mineral has the appearance of secondary hornblende. There are some augite grains. This is a fine-grained rock.

Nos. 4, 5, 6, 7, 8, and 9. These are all black slate. In section they are practically opaque. In some there are little crystals with clear borders and dark centers, crystals produced by metamorphism.

No. 10. This rock might be taken for a fine-grained eruptive greenstone, but under the microscope it has much the appearance of being a fragmental greenstone. The rock is much decomposed, but contains a large amount of augite and considerable granular iron ore. It is somewhat schistose, the crystals and cloudy masses being arranged along parallel lines. It is quite likely a fragmental rock.

No. 11. Also an augitic tuff. The rock mass is made up largely of augite crystals thickly matted together with cloudy material and granular magnetite. The cloudy material in these tuffs may have been originally the mud resulting from the grinding up of diabase fragments.

No. 12. This is an augite porphyrite, generally termed diabase or greenstone. The rock is much decomposed; shows prominent crystals of augite, but the feldspars have almost completely disappeared in a greenish, cloudy mass.

No. 13. Diabase or augite porphyrite. This is a fresher rock than the last, but of the same general character originally. It contains large crystals of augite, and smaller ones of feldspar in a cloudy decomposed ground-mass. The rock is somewhat talcose.

No. 14. This is a medium-grained diabase. Under the microscope it appears to consist largely of augite, with some small decomposed crystals of feldspar and iron ores.

No. 15. This is a fine-grained diabase tuff, and quite schistose. It is made up of augite grains, and faintly polarizing masses are arranged in layers with opaque seams between them.

No. 16. This is probably a greenstone tuff. It contains much cloudy matter, augite crystals, others which were once feldspar, and some which resemble hypersthene. Magnetite scattered through the rock.

No. 17. This is a talcose schist derived from what was probably a fragmental greenstone or tuff. The body of the rock is made up of thickly matted rods and scales of talc.

No. 18. Coarse diabase. This rock contains an excess of augite crystals fairly fresh in character, and a cloudy base in which outlines of feldspar crystals can be made out. It has been rendered schistose through pressure.

No. 19. Layers of augitic tuff and dark slate. Under the microscope the layers are seen to be made up of cloudy indeterminable material, through which are scattered fragments of augite crystals. They make up half of the rock. The dark bands contain

less augite and stringy opaque matter. They have the character of some of the slates except for the scattered augite fragments.

No. 20. In the hand-specimen, Nos. 20 and 21 look much alike. The rocks are coarse grained, with their dark constitutents altered to a green scaly talcose mineral. They contain much feldspar and cubes of iron pyrite. Under the microscope No. 20 is seen to consist of an acid plagioclase feldspar, perhaps oligoclase, quartz, and a green mineral replacing hornblende, also magnetite. This is a much decomposed rock, but might be termed a quartz diorite.

No. 21. Under the microscope this rock is seen to consist of a decomposed feldspar similar to No. 20, and green chloritic matter replacing some dark silicate, probably hornblende. This rock is also a diorite.

No. 22. This is a massive green rock made up of an aggregate of fine talcose scales. Under the microscope it appears very similar to No. 24, but shows no clue to its original mineralogical constitution.

No. 23. This is a green rock, which in the hand-specimen is almost massive; made up of an aggregate of fine lustrous scales. Under the microscope the rock is seen to consist almost entirely of a matted aggregate of interlacing scales with the properties of talc. There is also a little calcite and magnetite. This rock, then, is mainly a hydrous silicate of magnesia, replacing some magnesia-rich igneous rock. The precise nature of this rock cannot be told, for all traces of the original constituents have disappeared.

No. 24. This is a green talcose rock, showing dark gray and light green patches; the latter were probably once feldspar and the rock originally a gabbro. Under the microscope it appears to be made up of an interlacing matte of talcose scales.

No. 25. This is a coarse rock, and to the unaided eye appears to be made up of feldspar and chloritic hornblende. Under the microscope it appears to be made of cloudy feldspar, magnetite, and augite, partly altered to green hornblende. Might properly be termed a diorite, although it was once a gabbro when in a fresh condition.

No. 26. This is a feldspar porphyry, with bronze-colored crystals of mica. Under the microscope the feldspar is seen to be plagioclase. The rock may have contained augite once. Strictly, it might be termed a diorite porphyrite.

No. 27. This rock is very similar to No. 28. It contains more augite, and is quite fresh.

No. 28. This is a grayish rock, with rather indistinct porphyritic crystals of feldspar. Under the microscope it shows porphyritic crystals of augite and feldspar in a fine granular ground-mass. This rock is very different from the greenstones. It is lighter colored and fresher. It might be termed an augite porphyrite, although the feldspar might make it an augite-diorite porphyrite.

No. 29. This is a hard gray rock, with rather indistinct crystals of white feldspar. Under the microscope it appears to be badly decomposed, showing remnants of twined feldspar crystals, magnetite, and a dark constituent entirely decomposed. Might be termed a diorite porphyrite.

No. 30. This is a feldspar-quartz porphyry, showing large crystals of quartz, feldspar, and a bronze-colored mica in a fine ground-mass. Under the microscope the quartz appears much corroded, and the feldspars clouded. The ground-mass is made up of a fine-grained aggregate of quartz and feldspar.

No. 31. This rock contains hornblende, quartz, and plagioclase feldspar crystals in a granular ground-mass. In structure of components it lies between a granite and a porphyry and might be termed a granite porphyry.

No. 32. This is a rather fine-grained greenstone or diabase schist. It consists under the microscope of augite, pale green feldspar, probably labradorite, and iron ores. The constitutents are much altered.

No. 33. This is a quartz-feldspar porphyry. It contains crystals of twined feldspar (plagioclase), corroded quartz crystals, and a decomposed mineral possibly once hornblende. There may be some decomposed mica. These constitutents lie in a fine granular ground-mass.

H. W. FAIRBANKS, A.B.

In every mine accessible along the Central Lode, from the Pocahontas near Drytown on the north, to the Muldoon south of the Argonaut near Jackson, where ore-bodies are found in contact with or in slaty rocks, these slates are observed to be of the character described, and which the microscopic study of Mr. Fairbanks proves to be the result of alteration of tuffs, and not of massive diabase, as had been supposed by the writer.

The normal tuff is, however, massive, often fine-grained and containing crystals of augite, and difficult to distinguish from crystalline greenstone with the unaided eye; in this respect resembling the tuffs of Michigan, described by Mr. Williams, and those described by Captain Dutton as occurring in the Great Basin region of Utah.

The clay slates of the Mariposa beds are found in cross-cuts extending to the eastward and westward of the main fissures in these Amador mines. Usually the clay slates may be readily distinguished from the altered tuffs, but often the slaty tuffs graduate by insensible degrees into the clay slates, so that no line of demarkation is discernible.

It is rarely that the ore deposits are found in contact with the fine-grained clay slates, even for a short distance. In fact, the fissures, where passing through the clay slates are usually destitute of value in Amador County. This peculiar condition, however, appears to be local, as in Calaveras County the richest portion of the Gwin Mine is in a fissure cutting the black clay slates of the Mariposa beds, and in Mariposa County the Princeton Mine is wholly in the clay slates of the Mariposa beds.

In Amador County, however, it seems important to make the distinction, in view of the results obtained from veins in the clearly recognized clay slates and the pitted slates (altered tuffs). Although the mines of the old Plymouth Consolidated Company at Plymouth have not been accessible for many years, the dumps show a large amount of the tufaceous slate, and there is little doubt these slates accompanied the ore-bodies. Four miles to the northward, however, the Kretcher vein of the Bay State Company and the veins of the Rhetta Company adjoining it on the south, occur in the typical clay slates of the Mariposa beds, and in these mines are good-sized veins of banded quartz carrying payable values.

The Dolomitic Vein.—An important geological feature of the Central Gold Belt, and one which repeatedly appears from Mariposa to El Dorado County, is a great, dike-like vein of dolomitic mineral. This consists of carbonate of lime and carbonate of magnesia—a true dolomite—and in many places there is also found, in addition to the above minerals, carbonate of iron, forming ankerite.

This material occurs in great vein or dike-like masses, and is a prominent feature of the lode in Mariposa and Tuolumne Counties and the southern part of Calaveras County. It also appears near San Andreas,

and again near Jackson in Amador County, reappearing near Placerville in El Dorado County. Mariposite is nearly always present, often in large amount. Its beautiful green color led early prospectors to believe it was copper carbonate. The mariposite is not colored by copper, but by chromium.

The peculiar characteristics of the great dolomitic vein are no better shown anywhere along its length, perhaps, than at Coulterville and vicinity. Just below the village on Maxwell Creek, the great vein crosses that stream, which has cut a gap through it about 100 feet wide. On the south side of the creek is located the Louisa Mine, and immediately north of it is the Margaret, on the opposite side of the creek. Where the lode crosses the creek it has a width of 300 feet, and consists of an immense mass of ankerite, through which is disseminated the green, scaly mineral, mariposite. Large lens-shaped masses of quartz outcrop boldly from the ankerite, being somewhat harder than the latter. The lenses are irregularly distributed, but occur mostly along the hanging-wall and near the center of the vein. The large veins or lenses of quartz are separated by equally large or larger zones of the dolomitic mineral, which is interlaced in every direction by quartz veinlets and veins of varying size, making the entire mass a mineral zone or lode proper. One of the quartz lenses is nearly 20 feet in width, outcrops to a height of 25 feet, and is 300 feet long. A shaft sunk on the foot-wall side of it to a depth of 60 feet showed it to be thinning out; but there is no doubt that it would be found replaced in depth by another lens of a similar character.

South of this large cropping a small vein branches out into the hanging-wall diabase, striking northward and increasing in width until it disappears underneath Maxwell Creek. On the opposite side of the stream a large vein appears, which is apparently the northward continuation of the one referred to.

Through the center of the lode is a quartz vein 10 to 20 feet in width, and still west of it is another, but smaller vein. The entire western portion of the ankerite mass, constituting about one third of the whole width of the zone, is a perfect network of small quartz veins, stringers, and small bunches of quartz.

A prominent feature of interest is the union of two of the largest quartz lenses near the center of the lode by a third large vein, which crosses the intervening ankerite diagonally. The two large veins are about 120 feet apart. Beginning near Maxwell Creek, on one of the large outcrops referred to, a careful examination discovers a seam in the quartz, along which gold may be seen almost every foot of the way. This gold seam can be followed some distance in a southerly direction to where the diagonal branch above referred to leaves it. This latter also shows gold along a similar seam, leading to the other large quartz

lens parallel to the first, and here, again, is a gold seam which may be followed if care be taken. Outside of the gold thus occurring, none was observed elsewhere by the writer, though it was said that prospects could be obtained by crushing certain portions of the rock and carefully panning it.

Southward from the section above described, the several large veins converge toward a central point on the ridge, which rises higher and higher, terminating in an immense mass of quartz at its apex. Southward from this point the quartz is less prominent and the ankerite constitutes the major portion of the lode until another occurrence of quartz lenses is reached, which in each case, whether following the lode north or south, is much the same.

Gold sometimes occurs in the ankerite and mariposite, when seamed with quartz. A brecciated, crushed condition of this rock seems to favor the gold, or, at least, rock of this character contains more gold than that which is massive and solid. The entire mass is low-grade, and ankerite wholly free from quartz is practically free from gold in this mine.

The characteristics as above described are peculiar to the occurrence of the dolomitic vein wherever it appears. Often large masses of it are found crushed, sheared, and altered to talc schist or to a granular talcose mass, including many angular fragments of crystalline mineral. In the Rawhide Mine in Tuolumne County was found a notable exception to the usually observed condition. At one place in this mine the ankerite and mariposite were found phenomenally rich in gold.

As a matter of course, the description of the occurrence at Coulterville is not absolutely duplicated anywhere along the lode, but it is typical in its general features of the dolomitic vein throughout the length of the lode. In the Pacific Mine at Placerville, the talc schist resulting from the alteration of the dolomite contains 1 to 2 per cent of iron sulphide, but whether or not it is auriferous was not ascertained.

The mines of the Central Gold Belt, where not in the dolomitic vein, occur in black clay slates, in tufaceous black slates, and in amphibolite schist, and are described under their proper heading.

The East Lode.—The mines of the East Lode, which are found from 6 to 18 miles east of the Central Belt, occur in the slates of the Calaveras formation and in grano-diorite. Some of the most important of these mines are found in the latter formation, and a description of their general characteristics is of interest.

Granite areas in which gold-bearing veins occur are found in Mariposa County, near Hite's Cove; in Tuolumne County, near Groveland, near Columbia, and at Summersville and vicinity; in Calaveras County, at West Point and vicinity; in Amador, at Pioneer; in El Dorado, at several localities; and in Nevada County, at and near Grass Valley and Nevada City.

Veins in Granite.—In the several granite areas referred to occur a large number of veins, some of which appear entirely independent of all others, and in other instances are found systems of connected fissures, which were evidently produced by a common cause. These veins have definite characteristics, and the ores are noticeably similar throughout the entire granitic region referred to. They are usually easily distinguishable by their physical appearance from the ores occurring in other formations, whether in the same vicinity or from some distant point.

The strike and dip of these veins in granite are not at all uniform, in this respect differing greatly from the veins of the Central Belt, which almost universally strike west of north and dip easterly. In the granite areas the veins have no uniform strike, but are found from true east and west courses around to north, and at all angles between them. The dip is no more uniform than the strike. Whatever the direction of dip of a vein, it is usually not persistent at or near any particular angle, but varies from a low angle to nearly or quite perpendicular. Not infrequently, in depth a vein will dip in an opposite direction from that which it has at and near the surface. The veins occur along lines of fissuring. These fissures are found singly, in pairs, and in many places as zones of fracture of varying width, comprising several fissures having an approximate parallelism. These fissures, singly and in groups, are often planes of movement, as evidenced by slickensides and gouge seams. In many cases these zones of fracture are found to consist of crushed granitic material, greatly altered, and in some instances containing vein quartz in a granulated condition, indicating that a movement of the rock-masses has taken place subsequent to the deposition of the quartz. In certain more rare cases, this brecciated or granulated quartz has been cemented by a still more recent infiltration of silica. In these crushed zones the feldspars are thoroughly kaolinized; the bi-silicates are altered to chloritic mineral, and the whole mass is soft and, when wet, sometimes mushy, forming dangerous ground to mine. Often it is gold-bearing, though seldom rich.

In the same fissure plane or zone are found the concentrated mineral deposits forming the ore-bodies proper of the mines. In some places they lie at the side of these crushed, partially silicified zones, either in direct contact with them or separated by a strip or wedge of hard granite, but little altered. In other instances they are found as separate ore-shoots, connected with the previously described crushed zones only by a clay seam. Other masses of quartz occur in these fissures, which contain very little of either gold or sulphide mineral.

These veins are undoubtedly the result of substitution of silica, calcite, and other minerals for the original soluble constituents of the granite, having been conveyed to the point of deposition by mineral

solutions, probably derived from a deep-seated source. The most complete replacement has evidently occurred where the fissuring and crushing have been greatest. The vein quartz is found exhibiting every phase of condition from a partial alteration of the granitic mass, almost a normal granite (though the feldspars are always carious, and a small percentage of finely divided iron sulphide may usually be observed), through the various stages of transition, finally reaching the most complete alteration to crystalline quartz, sometimes heavily impregnated with the sulphides of iron, lead, copper, zinc, and silver, with gold and other minerals more rare. Calcite is a frequent accompaniment, both in the quartz and in the crushed zones of granite. The vein quartz occurs in a variety of conditions—as a vitreous, colorless, granular rock; a milk-white, semi-greasy kind; a bluish-black variety, usually vitreous; also in alternating bands of bluish and white rock, and as granulated quartz. All of these varieties are gold-bearing, and again all kinds are barren. All are associated with sulphide minerals, and all again occur with scarcely a trace of them. The banded varieties are usually of fair grade in gold, and the appearance of galena is often an index of value. Some of the zinc ores are also high-grade. The sulphide minerals contain from $50 to $1000 per ton in gold, and some are also correspondingly rich in silver, though the silver contents are usually relatively small. The sulphides are pyrite, marcasite, mispikel, chalcopyrite, galena, blende, and pyrrhotite. The latter is peculiarly characteristic of granite formations throughout California, particularly in the ore-bodies of larger size. Tellurides of gold occur sparingly in several localities. The ore-shoots vary greatly in width and length, though the veins sometimes have a width of 30 feet or more, as in the Black Oak Mine in Tuolumne County. Ordinarily, however, the shoots are less than 100 feet in length and average between 6 inches and 2 feet in width. Often the lenses have an average length of 20 feet, but succeed each other immediately, the ends often overlapping, thus forming practically a continuous shoot of considerable length.

Occasionally are found two veins approximately parallel and separated by 1 to 4 feet of granite in a more or less advanced condition of alteration, as is the case in the Good Hope Mine, near Perris in Riverside County. The branching tendency of the fissures is a pronounced characteristic. Usually one wall at least is well defined—generally the foot—the zone of fracture and crushing extending to various distances into the hanging-wall. Now and then a perfectly defined hanging-wall will be found, but progressing along this wall it is seen to diverge gradually from the plane of the foot and its influence as a bounding plane is lost, another slip or wall taking its place. This continues indefinitely until the identity of the entire vein is lost in the numerous branching cracks which extend into the granite. Often a well-defined vein several

feet in width will thus pinch out to the merest crack, in which is found no sign of clay or of movement, and it requires the most careful observation to follow it at all; but usually by persisting in the general direction of the course of the vein it may be found to reopen and new shoots of ore found. Sometimes, however, after drifting fruitlessly some distance, a cross-cut is advisable. In some instances these pinches are several hundred feet long and the ground very hard.

The formation of many short shoots of rich ore in portions of the fissure where the walls are several feet apart is an interesting feature. It is not uncommon to find a wedge of quartz forming on the foot-wall, which gradually widens to 1 or 2 feet when it leaves the foot-wall, crosses the fissured zone at a low angle, and joins the hanging-wall, where it thins out and is lost. Between the short shoot of ore thus formed and its parting from the foot-wall there may be found several stringers of quartz parallel with the foot, or the entire space may consist of a reticulated group of small veins and seams, while along the foot-wall a second wedge-shaped vein of quartz will appear, which will repeat the peculiarities of the shoot adjoining as described. The granite adjacent to the vein, and occurring as horses within it, is frequently gold-bearing to a considerable extent, sometimes in sufficient quantity to be visible to the naked eye.

It is the custom to sort out the granite as waste, but it should be done with caution, for it not infrequently pays to send the entire contents of the vein to mill, when in the pay shoot. The fact that several old dumps have been worked at a profit is evidence that early methods were careless in this regard. In some respects these mines are worked at a disadvantage, for it is easy to lose the vein where a pinch occurs, and it has led in numerous cases to the closing of what are probably good mines. What has been described as occurring along the vein horizontally is equally applicable to the fissure in depth, and a pinch in the shaft does not signify that the limit of the vein has been reached any more than it does when occurring in the face of a drift.

These disadvantages are greatly offset, however, by the high grade of ore, which is uniformly much higher grade than that in larger veins in other formations. Often the ores from the veins in granite may be shipped to distant smelters with profit after rough sorting.

Dikes are of frequent occurrence throughout the granite area in the neighborhood of the mineral belt. They are of various types, but the most common are granitic dikes of coarse crystallization and dark green diorites of fine grain, extremely tough and hard. The former are characterized by the occurrence of masses and crystals of albite, tourmaline, and biotite. The peculiar, interwoven, grate-like structure of quartz and feldspar, known as graphic granite, is of frequent occurrence in these dikes. These granitic intrusions are usually older than the veins,

though there are exceptions. The diorite dikes, however, are generally younger and cut the veins. The dikes, as a rule, cross the line of strike of the veins, though not always. Whether or not these dikes have any important influence on ore deposition is a question.

In some instances ore-shoots are found lying with the granitic dikes, the downward pitch of the ore-body being coincident with the dip of the dike. The influx of large quantities of water is a usual accompaniment of the development of these veins. It often comes with a rush at unexpected times. A mine may be developed to considerable depth and have encountered but little water, when without warning a blast will break into what is called by the miners a reservoir or pocket, though usually, in fact, a system of fissures filled with water derived from the surface. The deeper the point in the mine at which these water crevices are struck, the greater the force of the water. Often the lower levels are completely flooded, and weeks are required to pump out the water, but in time the reservoir is exhausted, and things resume their usual condition. Another water-rush may not occur in many months, and again in some places they have been found in quick succession. In one instance a water crevice was broken into in the Black Oak Mine in Tuolumne County at a depth of 600 feet. With considerable difficulty a bulkhead was constructed, and the pressure gauge indicated at one time a standing pressure of 180 pounds to the square inch, indicating that the height of this reservoir was not less than 400 feet. The flow being controlled by means of a valve, the pumps in time removed the water and a normal condition was again reached. After several months the bulkhead was torn out and a round of holes was drilled in the face and discharged, upon which the water again rushed into the mine workings in as great volume as before. The probability is that in some manner the vent to the reservoir had become clogged and the flow of water stopped. The force of the blast removed the obstruction, and the water again poured into the mine workings, but it finally was drained to a considerable extent. This shows the necessity for abundant capacity to handle water. Some claim that large flows of water are an indication of valuable ore deposits, but there is really no apparent relation between ore deposits and large flows of water. The ore was deposited by ascending currents, and the water found in mines is always found coming down from the direction of the surface. Sometimes water may be seen bubbling up from the lowest levels of the mine as though from an ascending current, but a case of this kind is due to hydrostatic pressure, the water flowing in coming from some point higher, through a series of connected cracks or fissures.

A peculiarity of these veins in granite near the surface may often be observed in the occurrence of open cracks traversing the vein in a horizontal direction, reaching from wall to wall, and dividing the vein into

blocks by a series of floors, as it were, at quite regular intervals of a foot or thereabouts, depending somewhat on the width of the vein. The blocks are separated by 1 to 4 inches of space, in which have accumulated clay and grit, quartz crystals, iron oxide, and other secondary products and gold. The amount of gold is largely in excess of the amount found in an equal weight of quartz of the vein itself in many cases. This peculiar occurrence is undoubtedly due to a sort of molecular expansion of the granitic mass, chiefly due to the alteration of the feldspars, and in a less degree possibly to the change which has taken place in the other constituents of the granite caused by surface decay and meteoric agencies generally. It is an interesting fact, and affords food for study and investigation.

The occurrence of gold in the silt-like material lying on these floors may be due partly to the quartz itself, but more probably comes from the oxidized sulphides, and also in part perhaps by infiltration from the selvages of the vein, if not from the granite itself, which may have become gold-bearing by impregnation from the fissure. Attrition, due to movement, may also have been partly responsible for the occurrence of this gold. When the oxidized zone is passed and the granite becomes normal, these floors no longer appear.

In many places the quartz is perfectly free from both walls, and again but one wall is free, the opposite side being frozen. In an equal number of cases the vein is frozen on both walls. These variations are not constant, for a vein may be free at one place and frozen in another. These changing conditions may be considered as indicating something of the relation of the original fissure to the ore deposit. Where both walls are free, it is not unlikely that the ore is filling the space bounded between two fissures. Where one wall is free the mineralization has progressed along one side of the fissure plane only; and where both walls are frozen, it would seem to indicate that ore deposition progressed outwardly from a single crack, or possibly, in the case of a large ore-body, the mineralization has impregnated the walls beyond the limiting planes of the fissured zone, to an extent sufficient to constitute ore, and has stopped only when the mineral solutions were unable to penetrate farther from the fissure plane itself.

METHODS OF MINING.

The mining methods in vogue on the Central Lode of California are not, in the opinion of the writer, those calculated to produce the best results, when viewed from the standpoint of economy. They are, with few exceptions, the methods of thirty, of forty, and of fifty years ago, and some of the practices are so primitive in their nature as to savor of past centuries rather than of decades.

A policy which obtains throughout the mining districts of California is that of demanding prompt returns from ore development, which is of course very desirable, but which in many cases works ultimately to the disadvantage of the owner, and the manager or superintendent is so completely handicapped that he is unable to make substantial headway. There are certain districts where this demand for "immediate returns" does not act so disadvantageously, but in the mines of the Central Lode it is undoubtedly a short-sighted policy. The reason for this will become apparent when it is understood that with few exceptions the ground is heavy—often swelling and crushing the heaviest timbers. The usual practice is to drive a cross-cut or drift from a station at the shaft to the vein. This may or may not at once encounter ore; if not, a drift is driven along the fissure, which must be timbered in the most substantial manner. These drifts are usually not less than 7 feet high, 4 to 5 feet wide at the top, and 7 to 8 feet at the bottom. These dimensions are all inside the timbers. It usually makes little difference whether the cutting is in ore or not, the ground is generally heavy. The fissures are often from 10 to 40 feet wide, and the miners (of Amador County particularly) are well acquainted with the danger, difficulty, and expense attending this kind of mining. As soon as pay rock is encountered it is hoisted and sent to the mill, and the drift continues, while overhand stopes are started and development proceeds. It may be several hundred feet to the limit of the property, and is often over 1000 feet, and this heavy swelling—sometimes running—ground must be kept open until the entire level has been explored and the ore to the level above all extracted and sent to the surface. An idea of the character of some of this ground may be gained from the statement that in a certain instance a drift of usual size being driven a distance of 200 feet, at the rate of 5 feet or more daily, under contract, could not be completed before it became necessary to return to that portion first driven for the purpose of retimbering. The timbers employed in holding ground of this character are usually 20 to 30 inches in diameter, and it is no uncommon thing to see these immense logs, a few weeks after being put in place, split, crushed, and broken as though they were incapable of offering any resistance to this all but irresistible force.

The advisability of cutting the main gangways in the hard rock of the walls, either foot or hanging, and reaching the vein by a system of cross-cuts, is advised. This has not, as yet, at this writing, been attempted, but its feasibility and desirability can readily be appreciated when the character of the main fissure, as above explained, is understood.

These main gangways, being driven in, say the foot-wall, should have cross-cuts extending at right angles to the direction of the main gangway. These should be disposed at stated intervals for the purpose of

prospecting the fissure and to render accessible the ore discovered. In slate, the main gangways should be at a distance of 40 to 60 feet from the vein—where in greenstone, they may be driven nearer the vein. The cross-cuts should be driven at stated intervals, a greater or less distance apart according to the character of the ground adjacent to the vein. When the ground is very bad, the cross-cuts should be closer, and when less so, at longer intervals. In most cases, if driven at intervals of 240 feet, the distance will be found convenient. Raises should always be put through, connecting with the level above, before stoping is commenced. Very often this important matter is neglected, owing, as previously stated, to a desire to realize a profit on the ore as quickly as possible. These raises should be put in about 60 feet apart; this, beginning 30 feet from the point where the cross-cut reaches the vein, will admit of four raises within the 240-foot section suggested, the vein being worked 30 feet each side of the raise.

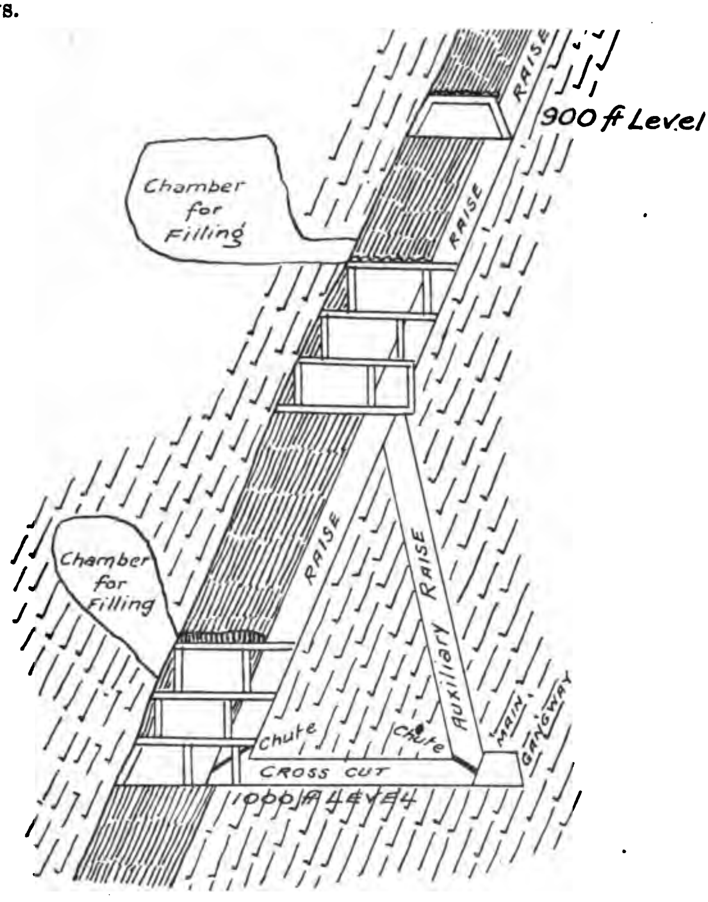
When putting through raises, it is really an economical plan to sink a winze from the level above to meet the raise. By this means ventilation will be more quickly obtained, and the additional work which men can accomplish will soon pay for the increased cost of sinking the winze. Men will not and cannot perform the best work most expeditiously in a foul atmosphere, though this fact seems to be lost sight of by many mine-owners.

In addition to the great disadvantage of foul air, when the raises are not put through, the heavy timbers must be hoisted through the raise into the stopes by means of block and tackle at great expense of time. If the raise were through, the cost of handling these great timbers would be very materially reduced by lowering them through the raise from the level above to the floor of the stope where they are to be placed in position.

With the lateral drifts and cross-cuts completed, and drifts driven on the vein, with raises through to the next level above, the work of stoping can be carried on at as many points as may be desired, and in a few weeks, or months at most, the greater portion of the excavation made on the vein, where not filled, will collapse and be closed up forever. This works no harm or inconvenience, as the main lateral drift remains open.

When operating in this manner, filling for the stopes may be taken from the hanging-wall by driving an inclined raise into it and opening out a chamber. The rock broken in these chambers will pass by gravity down into the stopes beneath and fill them, little or no shoveling being necessary. This method of mining and filling, when properly carried out, will prove more safe and far less expensive than some of the methods heretofore employed in California mines. In some mines, if stoping be expeditiously prosecuted in the manner above suggested, no filling will be required, the timbers affording all the support necessary, but in most

cases filling of the stopes is advised. Where the hanging-wall country adjacent to the vein has a tendency to cave, it may be that the inclined upraise for the purpose of obtaining filling for the stopes may be inexpedient. In that case, a horizontal cross-cut may be driven to the solid ground of the hanging, that portion nearest the vein being securely timbered. The filling must then be distributed by means of wheelbarrows.



Method of Working Veins in Swelling Ground,

FIG. 2.

These filling chambers may be worked with hand or power drills, large or small, as seems desirable. One of the greatest items of mining expense, as now practiced, is that of constantly relieving swelling or running ground, and retimbering. When the ore-shoot is attacked in sections by cross-cuts from the lateral drift, any particular section need remain open only a few months at most, instead of two, three, or more years, as now.

Another advantage may be derived by driving an intermediate level midway between the main levels, if the ground is particularly bad, and connecting with the cross-cut or gangway beneath by a raise. In this manner the floor of the lower main level need only be maintained about half the time that would be necessary if all ore were sent down to the main level through a mill-hole extending upward 100 feet more or less, and connecting two main levels. This plan would, of necessity, require that a raise be cut through solid rock from the vicinity of the main gangway to the foot-wall of the vein, reaching it about midway between two levels. Each of these raises would have an approximate height of 45 to 60 feet, and would cost, perhaps, when timbered, $500; but the expense of keeping open the level in the vein would soon offset this expense if the ground were very bad. As a matter of course, the superintendent must determine when an intermediate level and auxiliary raise are justifiable. His experience with the ground in the fissure will dictate whether the plan suggested is advisable or not. The sketch (Fig. 2) on page 29 illustrates the idea.

Timbering.—The timbers employed in the mines of the Central Lode are uniformly large—18 to 30 inches in diameter—and the method of framing and placing them varies somewhat, but is usually, in the larger stopes, some modification of the system known throughout the world as the Nevada square-set. The placing of these timbers is accomplished often under great disadvantage, and, in some instances, with considerable evident danger. The men selected for this work usually represent the finest type of physical manhood, for no others could accomplish the arduous task expeditiously. As to the relative merits of the respective methods of framing these heavy timbers, it seems only necessary to say that those systems involving the least framing with ax and adz underground, and consequent smaller loss of time in placing timbers in position, are the methods best adapted to regular practice.

In some mines an objection is raised to the employment of sills on the main floor of a level, for the reason that the sills rot before the stopes can be carried through from any level to the next above. In most cases there is no excuse for this. A reprehensible practice, which is found almost universal in these mines, is that of attempting to carry up stopes of too large a superficial area, and this practice is responsible for some disastrous caves which have occurred in various mines. A stope of smaller superficial area can generally be carried from one level to the next above more quickly and safely than a large one, and in most cases, even by the present "old-fashioned" methods of mining, a stope of small sectional area may be carried through in a few months—long before the sills become weakened by reason of decay. If the development of the mine were carried on well in advance of the extraction of the ore, it would not be found necessary to open these large stopes, as a num-

ber of smaller stopes would supply the same amount of ore daily as is usually drawn from one, two, or three large stopes, and it would be found that ultimately the cost would be materially less, as in most cases there would be no loss of ore, no disastrous caves, and work could be accomplished more expeditiously and more cheaply.

Filling.—There are few veins on the Central Lode where, by present mining methods, filling is not absolutely necessary, though by the adoption of the lateral foot-wall gangway system heretofore suggested, in some of the smaller mines, filling might to some extent be dispensed with, the walls being allowed to collapse after removing the ore. Material for filling is usually obtained from cross-cuts and drifts driven in prospecting, and from chambers cut in the walls of the veins—generally the hanging-wall. There are few veins on the lode so small as to make enough waste in stoping to fill the excavation. Ordinarily, all the rock removed from the pay-shoot goes to the mill, and filling must be obtained elsewhere. In some of the larger mines, where the veins are of great size—40 to 100 feet or more in width—it is not uncommon to find the entire vein removed for a distance along its strike equal to and often much greater than its width, the entire area overhead resting upon the props reaching from the topmost set of timbers to the roof. There may be three, four, or more floors in place, and the stope may be found filled from the sill floor to within a floor or two from the top; but it is clearly evident that in a stope of the size indicated, this filling can afford but little if any support to the hanging-wall, and none at all to the back of the stope. Failure to recognize this fact has resulted disastrously in more than one mine. The filling must be placed in such manner as to support the back of the stope over as large an area as possible, and a portion of this filling at least must be placed by hand, for it is clearly evident that should any subsidence occur in a stope approximating 100 feet square, timbers cannot be depended on to support the great weight. In a stope having a width and length of 100 feet and carried up four floors in height, there would remain between the top set and the floor of the level next above (65 feet) not less than 50,000 tons of ore. Should this become "dead weight," each post of the sets in place would have to sustain a load of several hundred tons of ore in addition to the weight coming from ore and filling in levels above, and to this must be added the greater pressure coming from the direction of the hanging-wall. This weight, or pressure, will vary greatly in different mines, depending upon the character of the ground, the condition of the walls, and to no small extent upon the angle of dip of the vein. Were the enormous weight of this great shifting mass of rock equally distributed, there would be less probability of a cave; but often, the weight being transferred from point to point, owing to the mobility of the ground, the pressure upon some given point becomes greater than the timbers can

sustain, and a single line of sets once forced out of position renders the remaining sets less secure than before, and general collapse results; and most miners are familiar with the dangers and extraordinary expense incident to the recovery of a caved stope and the extraction of the shattered masses of ore from the zone above the cave. In veins having vertical walls the danger of caves is much lessened, but the mines of the California Gold Belt dip at all angles ranging between 30 and 85 degrees, the greater number being between 45 and 70 degrees, below the plane of the horizon. This being the case, the pressure upon timber sets is exerted diagonally and not directly downward upon the posts of the sets. Naturally this renders the square, or rectangular, sets less capable of sustaining the weight and pressure. In some mines diagonal braces are set in to take this hanging-wall pressure more directly, but timber will not hold it.

In consideration of the above facts, the absolute necessity of filling becomes apparent, and the necessary preparations to this end should always be promptly made in order that the filling of the stopes be not too long delayed. Filling must be carried on contemporaneously with ore extraction; and in stoping, the excavations should be carried upward in sections of relatively small superficial area, the filling being packed as close to the back of the stope as possible. Where the veins do not greatly exceed 15 feet in width, the conditions are essentially changed, as in such cases the stopes may be timbered with stulls set slightly above a right angle to the dip of the walls. Most mines, where the walls are sufficiently firm, are timbered in this manner when the distance between walls admits of it. The conditions are so variable in these different mines, and often in different parts of the same mine, that the methods of timbering embrace almost every phase known in practice. The various methods of timbering employed in California mines and elsewhere were described and illustrated by the writer in Bulletin No. 2 of the California State Mining Bureau, February, 1896. See also method of stoping and filling at Eagle-Shawmut Mine, Tuolumne County, in this bulletin.

Drainage.—A very important factor in the economy of mining is the water encountered in the underground workings, and an ever-present question is the most inexpensive method of removing this incoming water from the mine. It is accomplished in three ways:—by natural drainage through tunnels; by means of pumps, or by bailing. This subject has been exhaustively treated in Bulletin No. 9 of the State Mining Bureau, by Hans C. Behr, M.E., and it is unnecessary to more than refer to it here. On the Central Gold Belt, and in fact throughout California, the large majority of mines bail water from sumps at the bottom of the shafts, or from tanks situated at various levels, where water descending from the surface and upper levels is caught.

Where the inflow of water is large, and the shafts are poorly equipped with hoisting machinery, with crooked, rough tracks or skids, the problem of bailing water, hoisting ore and waste, and carrying on development work—particularly that of sinking in the shaft—becomes a serious one, and sometimes it necessitates shutting down all work in the mine except that of sinking. Where this very undesirable combination of conditions is found, steam pumps are the most satisfactory, and it may be said that there is a growing tendency to the more extensive employment of steam pumps in mines of the Pacific Coast. In many cases steam pumps are found replacing the Cornish pumps.

In this connection, the following contribution will be of interest to mine managers generally. It was written by request for this bulletin by Mr. J. Renshaw, one of the foremost hydraulic engineers of the United States, and who has had a very extensive experience in mine-pumping operations where they were conducted on a large scale:

SOME OBSERVATIONS AS TO THE RELATIVE ADVANTAGES OF CORNISH AND DIRECT-ACTING DUPLEX PUMPS FOR PERMANENT MINE PUMPING.

By Mr. J. Renshaw, of Denver, Colorado.

(Written by request for this Bulletin.)

The following comparisons of the relative advantages of the higher grades of direct-acting, duplex steam pumps as compared with the old and well-tried Cornish system, refer to permanent pumping plants for mines in which the water is below the temperature of about 70° or 75° Fahr. When the water is above that temperature, it is evident that the exhaust steam from the direct-acting steam pumps cannot be advantageously disposed of, and either the Cornish pump, or some other plan in which the motive power is located at the surface, must be used.

Up to 1878 some one of the various modifications of the Cornish pump was exclusively used both in Europe and in this country. In that year, a simple cylinder, non-condensing, single-plunger pump at the Ontario Mine, Utah, with 12-inch plungers, 24-inch stroke, and 500 feet vertical lift, was altered into a compound, condensing pump by the addition of an expansion cylinder and a spool-shaped bushing put in the original cylinder, the space between the original bore and the outside of the bushing forming a steam jacket. This pump was, we believe, the first attempt toward a higher grade direct-acting steam pump located in lower workings for permanent mine pumping. It was thoroughly tested, first by the writer and then by the designer of a Cornish pump which had been selected by the writer to be put in, should the other not prove economical. It met with strong opposition, mainly from the builders of the Cornish pumps, both in California and the East, and with much skepticism of Eastern mine operators, principally, we think, with the belief that steam could not be conducted in pipes a long distance without a ruinous loss by condensation, and this idea held among many not familiar with the results of the compound, direct-acting, condensing steam pumps that had been put in, until 1884 and 1886, when they were put in a mine at Leadville and in one in Ishpeming, Mich., since which time very few Cornish pumps have been built in this country.

In 1882 or 1883, a Cornish pump was built for the Ontario Mine, which is no doubt the best example of that style of pump built, at least in this country. The writer had no opportunity to test it, but the manager of the mine said that he thought it saved a little in steam over the crude, direct-acting, condensing steam pumps that had been installed in that mine. When asked if he was sure as to any saving in steam, he replied that he was not, and later advised a mine operator in Leadville to put in the direct-acting, duplex condensing pump as against the Cornish pump, as the difference in cost more than balanced the possible saving in steam.

We know of no publicly reported experiments having been made to determine the amount of condensation in steam pipes until a series was made by the New England Board of Underwriters, and reported in the transactions of the American Society of Mechanical Engineers. The result then had, on pipes covered with one inch of hair felt and that by a thickness of burlaps, coincided almost exactly with what we had determined at the Ontario Mine with the same thickness of hair felt covered with 10-ounce canvas. At the Wolftone Mine at Leadville, the condensation in 585 feet of 4-inch wrought-iron pipe, covered with $\frac{1}{16}$ inch of asbestos paper, 1 inch of hair felt, and this covered with painted 10-ounce canvas, was 57.75 cubic inches per minute, or 8.396 cubic inches per minute for each hundred square feet of external pipe surface.

Judging by past experience, there is little difference in "duty" between the best examples of Cornish pumps and the best examples of direct-acting, compound condensing pumps, each, for say 1000 gallons per minute lifted 1000 feet vertically.

With triple-expansion, direct-acting, condensing pumps with the initial steam pressure at the pump at 140 pounds, and the pump running at say 125 feet piston speed, the comparison would undoubtedly be much in favor of it over the Cornish pump.

There are, however, other very important considerations to the mine operator as to the relative advantages of the two systems of pumping, besides a little difference in the steam economy. On a basis of 1000 gallons lifted 1000 feet per minute, the installed cost of the direct-acting pump will not reach 10 per cent of that for the Cornish pump. In most cases the working-out of the mine beneath the foundations of the Cornish pump engine will, by settlement, throw it out of line, it not being a self-contained machine like the direct-acting pump. So, also, with the "pit-work."

Another very important consideration is the expansibility—if we may so call it—of the two systems. When the size of a Cornish pump is to be determined, a large margin for increase of water through greater depth or side workings has to be allowed for, and what this margin is to be is difficult to determine. As a rule, but one Cornish pump can be installed in the one-pump compartment of the shaft, and it cannot be replaced by another without allowing the shaft to be flooded; and it is a question if it could be taken out as fast as the water would rise. This would depend upon the amount of ground worked out. Frequently there is allowed a greater margin for increase of water than afterwards proves necessary, either from the ore-body giving out, or less water being encountered than expected. The interest on investment, and wear and tear of a larger machine than necessary, are important considerations. Or, it may be years before the full capacity of the pump is called for. On the other hand, if too small a pump is put in, a new shaft has to be put down in which to install another and larger pump. Thus, the size of the pump has to be determined once for all.

Not so, however, with the direct-acting pump. They need only to be bought as depth is attained or increase of size becomes necessary. If the pump proves too small, a larger one may be installed on the pump station and the smaller one moved down to a lower level where less ground has been opened, and so on, making pump stations every 500 or 1000 feet. If the column pipe for the first pump put in is not of sufficient size for the larger pump, there is generally room enough to put in a larger one, and the smaller pipe then used below for the small pump. The expenditure for pumps may thus be by increments as needed.

As we have said, pump-shaft compartments are seldom large enough to install but one Cornish pump line, and "the eggs are all in one basket"; whereas with direct-acting pumps, two may be installed in the one station, both connected to one column pipe or each with its own, and in case of necessary repairs, one may be stopped and the other started. It is very comfortable for the mine operator to feel thus secure.

If there are two or more compartments to the shaft, one of which is for pump, piping, and ladders, that compartment should be well bratticed from the adjoining hoisting compartment. The heat radiated from even the well-covered steam pipe tends to make that compartment an "uptake" and the hoisting compartment a "downtake," and thus fairly good ventilation is to be had in the pump station or level.

We need hardly say that it is important to keep pipes and their bearers snugly to the sides of the shaft, so that there will be left a clear run for the rising of warm or foul air.

When, through the decomposition of pyrites or other minerals, the water is too hot for the condensation of steam below, then either compressed air may be substituted for steam, electric, or rope-driven power pumps, or the Cornish pump must be used. With

the utilization of mountain streams as a source of power, and either electricity or compressed air to transmit it, comes a new feature in mine pumping which will be more and more used, as in most of the metal-mining locations the cost of fuel is a "burning" question. The transmission of power to the station pump by electricity would present a simple solution of the difficulty were it not that the speed of the pump has to be varied, either because of increase of water by ground opened, or by the seasons affecting the surface water. We think this difficulty can be overcome without uselessly expending power.

The above is given as a summary of the relative advantages of the two systems of mine pumping, for a part of which we have to rely upon memory, but we are substantially correct.

The Diamond Drill.—In a number of mines of the Central Lode the efficiency and great desirability of the diamond drill as a prospecting device has been repeatedly demonstrated. It has been used with good judgment and excellent results at the mines of the Wildman Company at Sutter Creek, and also at the Baliol Mine near Sutter Creek, Amador County; in the Lightner Mine, Angels, Calaveras County, and elsewhere; and there seems to be a more general disposition to employ this machine for the purpose indicated, as by its means ore-shoots may be located at a distance from the main mine workings, either in the hanging or foot wall, at a minimum of cost. Not only is the proximity or the absence of ore demonstrated, but the character of the barren rock through which workings must be driven in order to reach such deposits is also ascertained, and the cost of development thus approximately determined. The diamond drill may also be employed in locating old workings, making connections for ventilation, and even in draining old flooded workings. Its use cannot be too highly commended in a region where there are broad zones in which occur ore-shoots scattered at irregular intervals, and this feature is particularly characteristic of large portions of the Central Gold Belt. The diamond drill may also be used to advantage in both the gold and copper mines of the West Lode.

THE COST OF MINING.

Another consideration is the cost of mining. This is something which can never arbitrarily be determined until the character of the mine has been demonstrated. The width and length of the ore-shoot must be known, and the character of the walls ascertained. The probable quantity of water which will have to be handled is always problematical, and, as a matter of course, the character of the walls and vein material itself will determine the method and expense of timbering. It is not uncommon to hear it said that in California mining and milling can be accomplished, under favorable conditions, for less than $1 per ton, but these conditions so rarely obtain, even in California, as to scarcely be worth mentioning, for they by no means constitute or illustrate the typical features of California mining. There are mines in slaty rocks not particularly hard, where the veins are 3 to 7 feet in

width, which, being worked through tunnels and having free water power, are operated at a very low cost, but even this class of mines does not represent the majority—indeed, such constitute a very small minority.

In the greater number of mines in this State operations are conducted through shafts, which necessarily increase the expense of mining. In the Central Gold Belt the mines vary so greatly in size, depth, character of ore and wall-rocks, and quantity of incoming water, that a statement of cost would convey but little information, and comparison would be valueless unless accompanied by a complete knowledge of existing conditions and an itemized cost-sheet. At a number of larger mines elaborate cost-sheets are kept, and to a number of these the writer has been given the freest access. The cost of mining in the larger mines, under ordinary conditions, may be fairly represented by the cost-sheet of the Wildman Company at Sutter Creek, which has been kindly furnished by the superintendent, Mr. John Ross, Jr.

DETAILED AVERAGE COST OF MINING ONE TON OF ORE

For the Years 1896, 1897, 1898, at the Mahoney Mine of the Wildman Company.

	Total Cost for 134,886 Tons.	Cost per Ton.
	Dollars.	*Cents.*
Timbers	24,499 18	18.163
Spiling	4,913 05	3.642
Lumber	1,017 57	.755
Charcoal	1,242 01	.92
Candles	1,840 59	1.365
Powder	4,386 75	3.252
Fuse	780 16	.578
Caps	186 05	.138
Water	7,538 00	5.589
Freight	1,338 42	.992
Iron	1,224 24	.908
Steel and steel rails	1,417 27	1.05
Hardware	3,139 48	2.328
Oil	775 37	.575
Grease and tar	117 27	.087
Coal	229 57	.170
Miscellaneous	3,241 69	2.403
Power-drill machinery	2,346 90	1.740
Surveying	667 50	.495
Cement	15 00	.011
Insurance	103 77	.077
Taxes	737 63	.547
Wire rope	636 28	.472
Office supplies	97 67	.072
Superintendence and labor	160,003 58	118.621
	$222,495 00	164.950

John Ross, Jr., Superintendent.

DETAILED AVERAGE COST OF MILLING ONE TON OF ORE

For the Years 1896, 1897, 1898, at the Mahoney Mill of the Wildman Company.

	Total Cost for 134,901 Tons.	Cost per Ton.
	Dollars.	*Cents.*
Shoes	2,310 00	1.712
Dies	2,078 63	1.541
Screens	441 97	.328
Quicksilver	870 14	.645
Hardware	1,199 05	.889
Water for power	10,699 60	7.931
Freight	1,064 00	.789
Cyanide potassium	162 00	.120
Wood	220 88	.164
Charcoal, iron, and steel	97 74	.073
Oil	63 95	.047
Grease	23 13	.017
Lumber	67 34	.050
Miscellaneous and coal	1,529 46	1.134
Timbers	17 95	.013
Assay supplies	516 59	.382
Office supplies	275 73	.204
Expressage, bullion	391 16	.290
Hauling and loading sulphurets	2,354 65	1.746
Silver-plating plates	281 50	.208
Insurance	423 14	.314
Taxes	701 11	.520
Plates	86 49	.064
Superintendence and labor	16,791 58	12.447
	$42,667 79	31.628

The above cost includes all repairs and equipment.

JOHN ROSS, JR., Superintendent.

Following is the cost-sheet of the Gwin Mine, Calaveras County, for the month of July, 1900, which is kindly furnished by Mr. J. J. Crawford, secretary of the company:

DETAILED COST OF MINING, MILLING, AND SULPHURETS AT THE GWIN MINE FOR THE MONTH OF JULY, 1900.

	MINING And Transporting to Mill 7,965 Tons.	MILLING 8,000 Tons.	SULPHURETS Concentration, Transportation and Reduction Charges on 108.545 Tons.
	Cost per Ton.	Cost per Ton.	Cost per Ton.
	$ cts.	cts.	$ cts.
San Francisco office—salaries, directors' fees, and expenses	.0082	.0084	------
Management	.0314	.0313	------
Mine office—salaries and expenses	.0129	.0075	------
Labor	1.3886	.0653	3.418
Water	.0650	.0875	.746
Electric light	.0013	.0022	.051
Timbers	.2754	------	------
Lagging	.0692	------	------
Wedges	.0103	------	------
Lumber	.0050	.0031	------
Powder	.0470	------	------
Fuse	.0080	------	------
Caps	.0020	------	------
Candles	.0335	------	------
Drill steel	.0085	------	------
Iron and steel	.0014	.0013	------
Tools and implements	.0055	------	------
Hardware	.0201	.0005	------
Charcoal	------	.0003	------
Oils and lubricants	.0035	.0017	------
Shoes and dies	------	.0600	------
Screens	------	.0007	------
Chemicals	------	.0002	------
Average loss of quicksilver of four years	------	.0070	------
Miscellaneous supplies	------	.0020	.275
Surveying	.0072	------	------
*Assaying apportioned	.0008	.0034	.212
*Blacksmith shop apportioned	.0341	.0053	------
*Pumps and repairs apportioned	.0301	------	------
*Power drills and repairs apportioned	.0017	------	------
Legal expense	.0025	.0006	------
*Equipment and construction apportioned	.0413	.0665	------
§Development apportioned	.0045	------	------
Taxes apportioned	.0370	.0081	------
Stable and animals apportioned	.0082	.0006	------
Compressor—labor and supplies	.0272	------	------
*Compressor apportioned	.0210	------	------
*Telephone line apportioned	.0012	.0004	------
*General improvements apportioned	.0100	.0038	------
Hauling sulphurets and back freight on sacks	------	------	2.203
Reduction charges and railroad freight on sulphurets	------	------	9.491
Total cost per ton	$2.2236	$0.3677	$16.396
For purpose of comparison, following items may be transferred from "Sulphurets" to "Milling" column:			
Labor	------	.0464	------
Water	------	.0100	------
Electric light	------	.0007	------
Miscellaneous supplies	------	.0037	------
Assaying	------	.0028	------
Total	------	$0.4313	$11.694

*Because of the deterioration of the machinery, etc., represented by these accounts, one per cent per month of their cost and repairs is inserted in this report.

§The development is apportioned according to the estimated life of that part of the mine affected by it.

At the Kennedy Mine, Jackson, Amador County, it may be stated without particular reference to detail, that the cost of mining, milling, and all development work, including the new vertical shaft and expense of conducting chlorination works, is about $5 per ton. The details of the Kennedy cost-sheet are not available for publication, as the company does not carry their cost-sheet out in all its minutia, being satisfied with more general statements of cost and profit, but it may be stated that the great apparent discrepancy as compared with that of the Wildman Company's sheet is due to the extremely unlike conditions obtaining in these two mines, which are not more than two miles apart. The Kennedy vein is much smaller than the great ore-shoots at the Wildman, but in the former they are seldom without heavy swelling ground, which, under the system of mining carried on for years at the Kennedy and other similar mines, requires constant relief and frequent retimbering. This comparison is made merely for the purpose of showing that comparisons of cost without a complete knowledge of the conditions affecting such cost, are practically meaningless, and are unjust to the mine managers who are willing to furnish such figures.

It should be remembered in the case of the Wildman Company's sheet that it includes the years 1896–97–98, but does not include the years 1899–1900. Within the past two years there has been a very material advance in the cost of many mining supplies and in mining machinery. The mine cost-sheet would be affected particularly in the items of iron, steel, steel rails, hardware, power-drill machinery, wire ropes, etc., and the mill sheet would show a probable increase in cost of shoes, dies, screens, quicksilver, hardware, iron, and steel. This increase in cost of the items enumerated would raise the cost of both mining and milling, and as a matter of course, would affect all other mines in proportion to the magnitude of their operations. At those mines treating the largest quantity of ore per stamp the milling cost would be lowest, and at those mines hoisting the largest tonnage of ore to the number of men employed the mining cost would be lowest. Ordinarily, in the larger mines, the cost of timbering ranges from 30 cents to 50 cents per ton of ore extracted.

MINING MACHINERY.

There is found in the Gold Belt a great diversity of mining machinery, from the crude windlass to magnificent plants costing many thousands of dollars. When it is determined to purchase a hoisting plant, it is always advisable to select such machinery as the conditions under which it is to work, and the object desired to be accomplished, shall justify. When it is the intention to sink a shaft to great depth, it is

the best policy to purchase light machinery at first, and at the depth of a few hundred feet, when necessary, to exchange this for heavier machinery, but not heavier than seems absolutely necessary to accomplish the work in hand. Very heavy and expensive hoisting gear is not advisable for shaft-sinking, nor before the mine has been developed to a stage indicating the necessity of such a plant for the purpose of hoisting large quantities of rock within a limited time. For instance, it would scarcely be considered wise to equip a shaft through which it is expected to raise 400 tons of ore daily, with machinery capable of handling ten times that amount. Heavy and expensive machinery is only justifiable when there is sufficient work for it to perform. There are, usually, at least two active periods in the life of a mine, which are distinctly separate. These are, first, the prospecting period; and second, the productive operating period; though many mines never pass the first stage.

Among the large new enterprises in the Gold Belt, the operations of the Mariposa Commercial and Mining Company, on the Mariposa Estate, are worthy of more than passing notice. These people, with probably the largest available capital for mining operations in the State, are prospecting five mines on their property. Everything is being done in a thorough, workmanlike manner, at the lowest possible cost, without the exercise of parsimonious economy. The machinery in use is first class and exactly suited to the work for which it is being used; that is, prospecting. When the limit of utility of these machines has been reached, others of heavier design will be substituted, and the lighter machines employed elsewhere, but no great outlay for plant will be made until the development of the mines justifies it. In this respect, at least, the management of these properties is entitled to great credit.

MINE BELL SIGNALS.

It having come to my notice that in some localities the legalized code of mine bell signals is not in use, it appears important to call attention to the fact that the California State Legislature adopted a code of mine bell signals May 1, 1893, which should be adopted by all mines regardless of custom or different practice elsewhere. There is a liability attached for the non-use of the legal signal code. For the benefit of California miners the legal signal code is here published.

California Code of Mine Bell Signals.

1 bell, to hoist. See Rule 2.
1 bell, to stop, if in motion.
2 bells, to lower. See Rule 2.
3 bells, man to be hoisted; run slow. See Rule 2.

4 bells, start pump if not running, or stop pump if running.
1—3 bells, start or stop air-compressor.
5 bells, send down tools. See Rule 4.
6 bells, send down timbers. See Rule 4.
7 bells, accident; move bucket or cage by verbal orders only.
1—4 bells, foreman wanted.
2—1—1 bells, done hoisting until called.
2—1—2 bells, done hoisting for the day.
2—2—2 bells, change buckets from ore to water, or vice versa.
3—2—1 bells, ready to shoot in the shaft. See Rule 3.

Engineer's signal that he is ready to hoist is to raise the bucket or cage two feet and lower it again. See Rule 3.

Levels shall be designated and inserted in notice hereinafter mentioned. See Rule 5.

For the purpose of enforcing and properly understanding the above code of signals, the following rules are hereby established:

Rule 1. In giving signals make strokes on bell at regular intervals. The bar (——) must take the same time as for one stroke of the bell, and no more. If timber, tools, the foreman, bucket, or cage are wanted to stop at any level in the mine, signal, by number of strokes on the bell, the number of the level first before giving the signal for timber, tools, etc. Time between signals to be double bars (— —). Examples:
6— —5 would mean to stop at sixth level with tools.
4— —1—1—1— —1 would mean stop at fourth level, man on, hoist.
2— —1—4 would mean stop at second level with foreman.

Rule 2. No person must get off or on the bucket or cage while the same is in motion. When men are to be hoisted, give the signal for men. Men *must* then get on the bucket or cage, *then* give the signal to hoist. Bell cord must be in reach of the men on the bucket or cage at station.

Rule 3. After signal "Ready to shoot in shaft," engineer must give the signal when he is ready to hoist. Miners must then give the signal of "Men to be hoisted," then "spit fuse," get into the bucket, and give the signal to hoist.

Rule 4. All timber, tools, etc., "longer than the depth of the bucket," to be hoisted or lowered, must be securely lashed at the upper end to the cable. Miners must know they will ride up or down the shaft without catching on rocks or timbers and being thrown out.

Rule 5. The foreman will see that one printed sheet of these signals and rules for each level and one for the engine-room are attached to a board not less than twelve inches wide by thirty-six inches long, and

securely fasten the board up where signals can be easily read at the places above stated.

RULE 6. The above signals and rules must be obeyed. Any violation will be sufficient grounds for discharging the party or parties so doing. No person, company, corporation, or individual operating any mine within the State of California shall be responsible for accidents that may happen to men disobeying the above rules and signals. Said notice and rules shall be signed by the person or superintendent having charge of the mine, who shall designate the name of the corporation or owner of the mine.

Section 3 of the law says: "Any person or company failing to carry out any of the provisions of this Act shall be responsible for all damages arising to or incurred by any person working in said mine during the time of such failure."

AMADOR COUNTY.

Since the publication of the last report of the State Mining Bureau on the mineral resources of the State, Amador County has taken a leading place in the movement toward modern mining practice. The old-time mining methods, in many cases, have been cast aside for more modern ideas, and it may be said that a new era in mining has only commenced.

In this county are a number of the deepest mines in the State, as well as some of the most valuable. Since the early days of mining in this county, it has been the common belief that the essential feature of a paying mine in Amador was a contact of greenstone and black slate. The development of the last few years has proven that this is not absolutely necessary, for some of the best ore-shoots found in this county are in amphibolite schist, and not associated with any contact. Another erroneous impression has been that all ore-shoots must necessarily be found in connection with the black clay slates of the Mariposa beds. To such an extent has this belief obtained, that it was considered almost useless to look elsewhere for paying mines. Investigation of the past season has demonstrated beyond a doubt that the clay slates of the Mariposa beds have little bearing upon the value of the ore deposits, and that the black slates found associated with these ore deposits are the result of an alteration of diabase tuffs, and may usually, if not always, be readily distinguished from the clay slates. Moreover, the ore deposits do not occur for any considerable distance on the contact of these slates and the massive greenstone, but are independent of them throughout the county. This subject has been treated at some length in the opening paragraphs of this volume.

Between the southern limits of the town of Jackson and the Mokelumne River on the Central Gold Belt, there are at present no mines which are paying, although active operations are in progress on several properties included in that section and profitable mines may be developed. The first mine, coming from the Mokelumne River northward, which may be included in the paying class, is the Zeila Mine. In this county, since our last report, a number of old mines have been reopened, after an idleness of years. The most important of these are the Oneida, Central Eureka, Lincoln, and Bunker Hill, descriptions of which will be found in the following pages. The Baliol Mine, near Sutter Creek, is a new mine which has been extensively equipped and developed since the publication of the last report.

Amador Queen No. 1.—This mine is 1½ miles south of Jackson. The shaft has been sunk to a depth of 1200 feet, with extensive development at the 160, 300, 500, 1100, and 1200 foot levels. All of the workings of the mine are in amphibolite schist. Heavy gouges are an important and characteristic feature of this mine. There is a broad zone of schist, much foliated and contorted, with the frequent occurrence of seams and veins of quartz, with occasional high values; galena and free gold are often observed. Between the 1100 and 1200 foot levels a new shoot of ore has recently been discovered, which is one of the most promising observed in the mine. The shaft in this mine has two compartments, and is sunk at a cost of about $30 per foot. Power is furnished by water under a head of 270 feet, and transmitted by Manila ropes to the hoist. There are 15 men employed.——The Jackson Exploration and Development Company (Ltd.), owners. James E. Dye of Jackson, superintendent.

Amador Queen No. 2.—It is 1½ miles south of Jackson, and west of Amador Queen No. 1. The mine is opened through a cross-cut tunnel run 1000 feet to the vein, where a station has been cut underground and a double-reel hoisting plant installed. It is run by water power from a reservoir situated on the hill above, the pipe-line being conducted through an old shaft. There is a head of 312 feet at the hoist. A three-compartment winze has been sunk at a uniform angle below the adit, the vein dipping irregularly. In January last, the shaft was down 730 feet below the tunnel level. The vein occurs in amphibolite schist, and is chiefly interesting for the amount of arsenical sulphide (mispickel), rich in gold, which it contains. This ore is shipped; all work done in the mine is performed by hand, no machines being in use. The property is equipped with a 20-stamp mill; 19 men are employed.——The American Improvement Company of Toledo, Ohio, owners. John R. Phillips, superintendent.

Anderson (New York) Mine.—It is 3 miles southwest of Jackson, near Jackson Creek. The mine consists of a number of ore-shoots or mineralized zones, which occur in a dense aphanitic rock, the exact character of which has not been determined—probably a diorite-porphyrite. The ores are found in the crushed portions of this mass, and consist of impregnations of iron sulphides, free silica, and gold. The oxidation of these deposits has resulted in the formation of silicious iron ores carrying free gold. The mine is developed by means of three tunnels: one a cross-cut, 900 feet in length; the second a cross-cut and drift, 300 feet; the third a drift, 150 feet. A winze has been sunk in the latter 70 feet in depth, with a cross-cut 100 feet. In addition to this there are numerous superficial pits and open cuts along the croppings. There is a building for a 20-stamp mill on the property. In this at one time a Huntington mill was in use, in which was crushed

2500 tons of this ore, but a mill of this type is not well suited to the extremely hard, dense ore found in this mine. A ditch carrying 400 inches of water, which at the mine has 300 feet head, is a portion of the property.——W. G. Anderson of Jackson, owner.

Butte Mine.—It is a prospect 5 miles southeast of Jackson, near Jackson Butte; is opened by means of a tunnel, and has a 10-stamp mill. A small force at work. Not visited.

Spagnoli Mine.—This is at Clinton. The property was being operated last spring by the Hobart Gold Mining Company of San Francisco. It has an old inclined shaft 110 feet in depth, and a new vertical shaft 220 feet in depth. The vein occurs in granite. The mine was not visited.——S. N. Spagnoli of Jackson, owner.

Peerless Mine.—It is 2 miles southwest of Jackson and about 3 miles south of the Kennedy Mine. An inclined shaft has been sunk at or near the contact of black clay slates of the Mariposa beds, which occur on the foot-wall and a diabase tuff on the hanging-wall. At the surface was discovered a small vein of quartz, which prospected well in gold. There are 10 men employed.——Peerless Mining and Development Company of Jackson, owners. Henry Osborne of Jackson, superintendent.

Kirkwood Mine.—A new property adjoining the Peerless on the south. It is in the prospective stage.

Zeila Mine.—It is in the southern limits of the town of Jackson. Since the last report, the shaft has been sunk from 1160 feet, at which depth it had remained for some years, to 1506 feet, the lowest level being opened at 1350 feet. The mine was first worked about forty years ago, and continuously for the last twenty-one years. The property has a 40-stamp mill, which was worked steadily for fifteen years, when the mortars of old style were replaced by modern heavy mortars, provided with liners, etc. A modification of the Nevada square-set system is employed in timbering this mine. It is substantially the same as that used at the Utica Mine, Angels, Calaveras County, but was first introduced in the Zeila Mine.

The Zeila ore-shoot occurs as a broad zone of amphibolite schist and quartz, 30 to 40 feet wide. The ground is heavy and expensive to hold. Never a rich mine, it has always, however, paid a small profit. Filling is necessary in working this mine, and is obtained from the vein and also from chambers cut in the hanging-wall. The chlorination works at this mine have been entirely replaced once, and the hearths renewed several times; a hearth usually lasts about five years. The manager states that the average expense of mining and milling at the Zeila is about $3 per ton. In recent years a canvas plant has been added to handle the tailings from the mill. 115 men are employed.——Zeila

Mining Company of Jackson, owners. W. F. Detert of Jackson, superintendent.

The Zeila Mill.—The mill, which is under the direction of B. F. Taylor, has 40 stamps which weigh 818 pounds, new. The rock is crushed at the hoist with Blake breakers 9x15 inches. The mill is supplied with Hendy Challenge feeders. The stamps drop 7½ inches, 87 times a minute. The screen used is No. 16 brass wire. The discharge is 7½ to 9 inches high; it is regulated by the introduction of 2-inch differential chuck-blocks. The capacity is 4 tons daily. There is one inside plate on the chuck-block. The pulp from the screen falls against a splash board and drops upon an iron plate (the lip of the mortar), from which it drops 1 inch to an apron plate 51 inches wide by 30 inches in length; thence it passes to the sluice plates 16 inches wide by 120 inches in length. The pulp passes by launders to the vanners. The free gold constitutes but 35 per cent of the values. The plates are dressed daily and a clean-up made mohthly. Experiments have shown that while finer crushing will result in saving more free gold, there is a greater loss of values in sulphides, due to sliming of the ore. The iron shoes and dies last 100 days, crushing 400 tons of ore. In the Zeila mortars there is a tendency of the center shoes and dies to wear more rapidly than those at the end of the mortar. Raw copper plates are used, and it is rarely the amalgamators have any trouble with copper salts or spots of any kind on the plates which have never been silvered. This is considered due to the character of the ore, consisting largely of chlorite schist with quartz, and containing no rapidly decomposing sulphides. Mr. Taylor, mill foreman, states that but twice has he ever detected visible gold in the ore. The sulphides occur to the amount of 2½ per cent, and have a value of about $100 per ton, which is in strong contrast with other mines where the average value of the ore is higher than at the Zeila. At the chlorination works, 7800 pounds of sulphides are treated daily in three charges of 2600 pounds each. The furnaces are 60 x 11 feet, inside measurements. The Plattner process is employed.

The Zeila Canvas Plant.—The slimes plant is located at the mill. Owing to the fact that the issue from the mill is near the creek level, the tailings are elevated by a centrifugal pump to a height of 13½ feet to a hydraulic sizer or separator; 6½ inches (miner's) of water are required to run the pump under a head of 150 feet. The daily output of tailings consists of 32 inches of water and about 150 tons of sand, the output of a 40-stamp mill. The hydraulic sizer, which is a modification of the well-known German spitzkasten, is an invention of Mr. Hambric, who is in charge of the plant. The accompanying illustration (Fig. 3) will give an idea of the construction and operation of this device. The pulp falling into the separator, passes into the first upright pipe in the box, in which is a smaller pipe with a jet of water under pressure. This

causes a violent ebullition of the sands, the coarser particles of which pass out at the bottom, the finer rising from the tube, re-entering the separator and passing onward to the second pipe, where it undergoes a similar operation by means of a second hydraulic jet. Here the sands pass out at the bottom, the slimes rising as before and passing out through a launder opposite the end at which they enter. The coarse material from the separator goes to two canvas tables, which accumulate about 1½ tons of sulphides per month; the grade of these tables is 3 inches in 1 foot, which is the heaviest grade in the plant. Tailings from these tables go to waste. The finer pulp from the separator goes

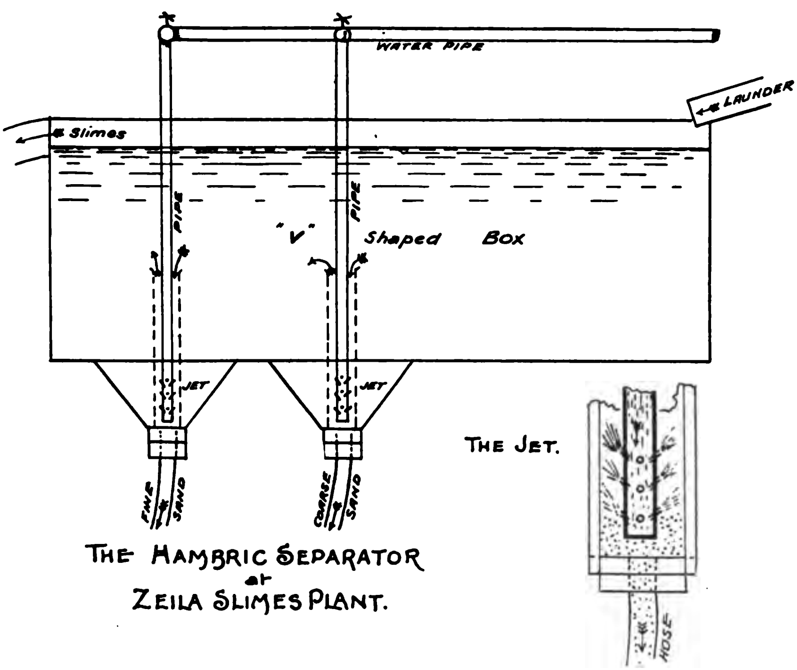


FIG. 3.

to the tables of the main plant, which are in a building 58 x 140 feet. The plant consists of 32 main tables, 10 x 12 feet, and 8 auxiliary tables, for the purpose of taking the overflow when purifying the tables of the main plant. The grade of these tables is 1¼ inches to the foot. The pulp is divided into four equal portions outside the building, and is evenly distributed on an inclined plane provided with ribs 3 inches apart, ¾ inch deep, and ½ inch wide. Along these channels the pulp flows to the canvas tables. There are eight divisions at the upper end, which grow less in number as each table is passed, until the last of the series is reached, where there is but one. At the head of each table is a

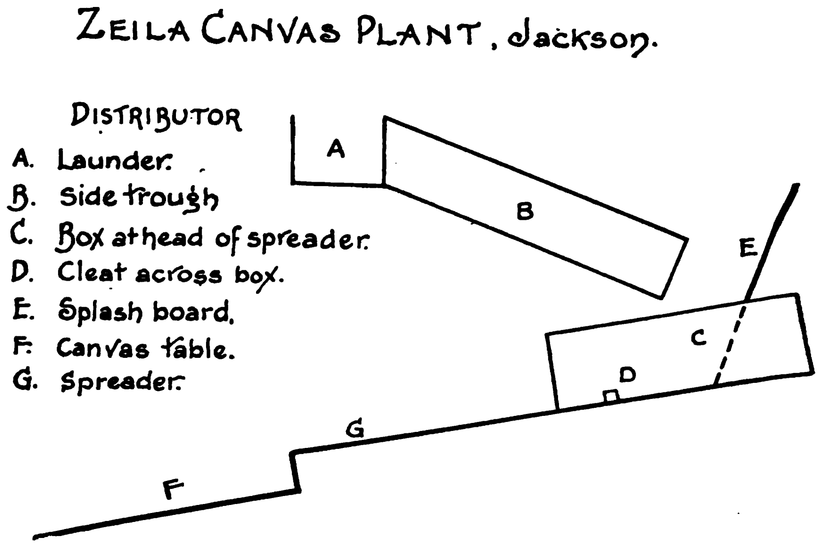

ZEILA CANVAS PLANT, Jackson.
DISTRIBUTOR
A. Launder.
B. Side trough
C. Box at head of spreader.
D. Cleat across box.
E. Splash board.
F. Canvas table.
G. Spreader.
A
B
C
D
E
F
G

FIG. 4.

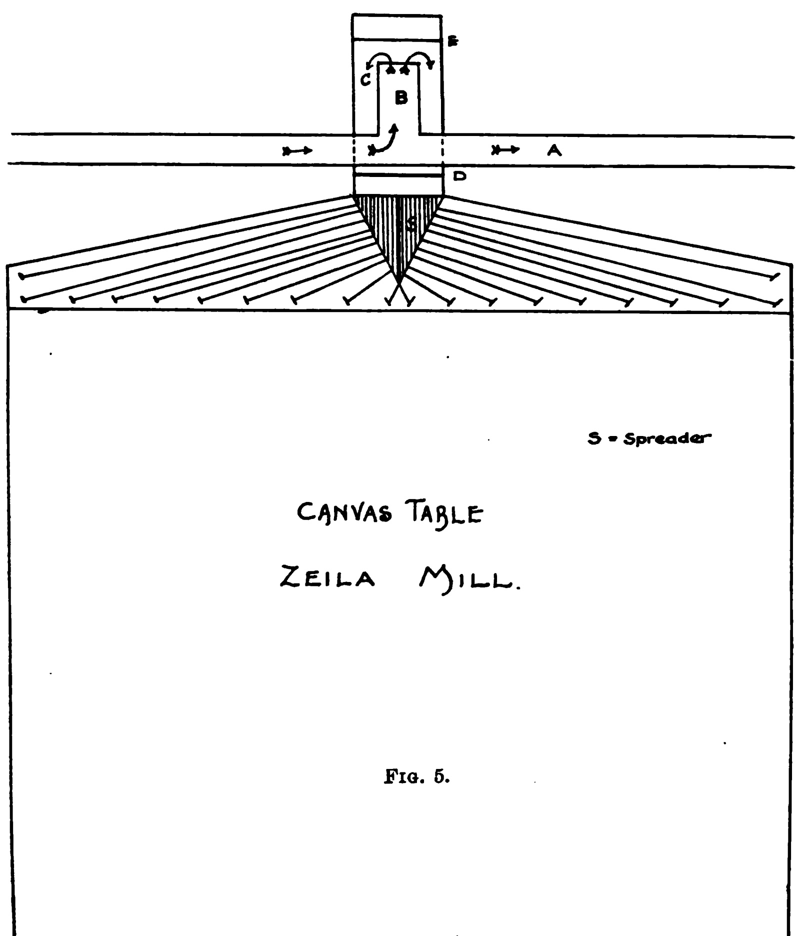
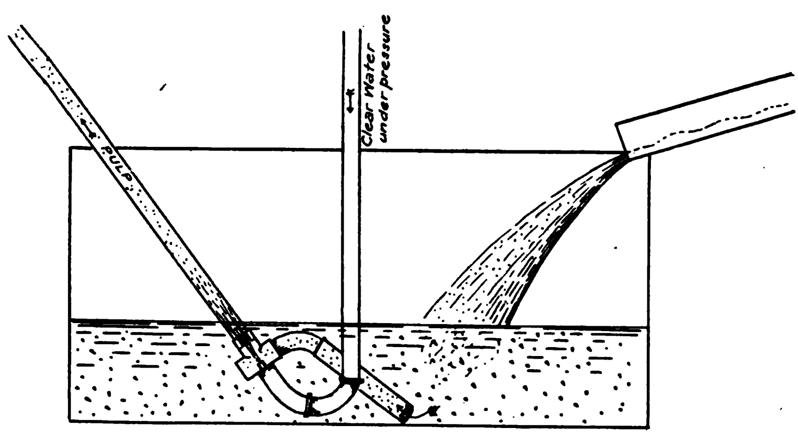

E
C
B
A
D
S
S = Spreader
CANVAS TABLE
ZEILA MILL.

FIG. 5.

distributing device illustrated in the accompanying sketches (Figs. 4 and 5). Throughout the length of the plant clear-water pipes are provided with faucets opposite each distributer, and between each of two tables is a hose for washing the tables. At this plant the owners undertook a series of experiments, of which the chief feature was the discontinuance of purifying the material concentrated on the canvas, by washing off the lighter sands before collecting the sulphides. At this writing (June 10th) the result of this experiment has not been ascertained. At the foot of the tables are two launders, one for waste, the other for sulphides collected on the tables. These are kept separate by means of a movable bridge or apron. The washings from the tables are re-concentrated on a belt machine, 1000 pounds being reduced to 900 pounds. All pulp from the tables is elevated by means of two



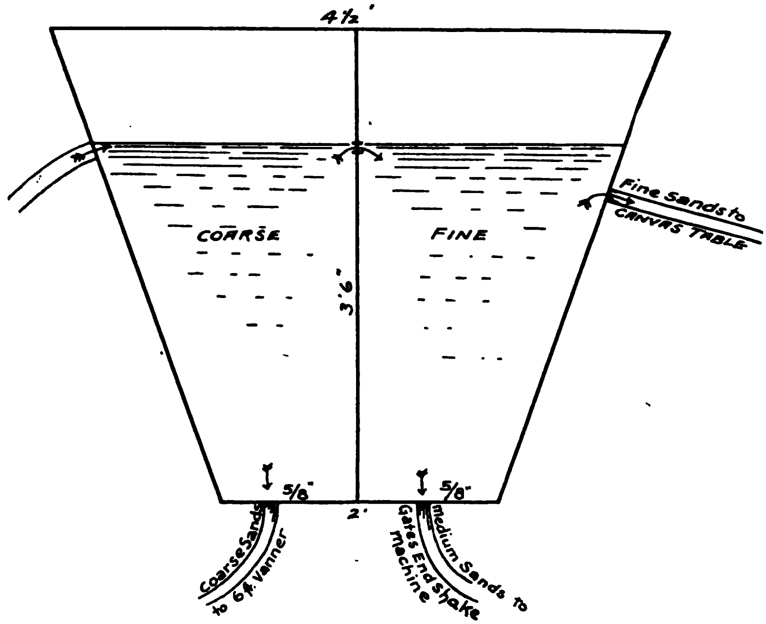
HYDRAULIC EJECTOR or PUMP at ZEILA SLIMES PLANT
Jackson, - Cal.

FIG. 6.

hydraulic ejectors, the construction and operation of which is illustrated in the sketch (Fig. 6). The pulp passes to a box having the form of an inverted truncated pyramid, 4½ feet square at the top, 18x24 inches at the bottom, and 3½ feet deep. The construction and operation of this device is shown in Fig. 7, on p. 50. As previously stated, the practice of purifying at this plant has been discontinued; the experiment has demonstrated that by sending the concentrates from the tables to the pointed box effects a saving of from 12 to 15 tons per month, but it also results in lowering the grade of concentrates. The economic result, however, has not been determined. No. 8 canvas is employed in this plant, and lasts one year. Canvas for the complete plant costs $175. The wear and tear of the plant is stated to be about $25 per month; the

plant cost complete about $6,500.——Groome & Hambric of Jacks[...] owners.

Argonaut Mine.—One mile north of Jackson, adjoining the Kenne[...] on the south. The inclined shaft commenced in 1893 has now reach[...] a depth of 1750 feet, at which point it was stopped by an injunction [...] the court, pending a settlement of litigation with the Kennedy Com[...]pany. Above this level the mine has produced a large amount of or[...] which has been crushed in a 40-stamp mill with large profit. Th[...] shaft not being sunk on the vein, a series of raises have been driven[...] which prove this vein to be continuous from the surface croppings t[...]



POINTED BOX - ZEILA SLIMES PLANT.

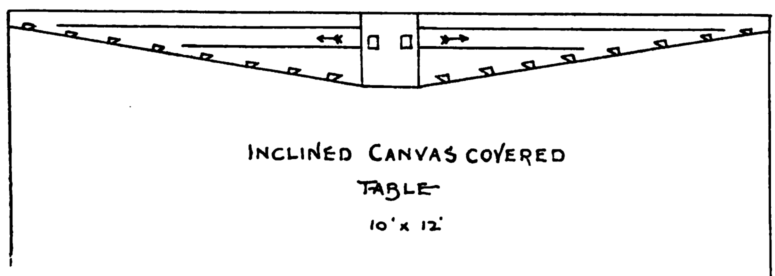
FIG. 7.

the lowest workings. The mine is equipped with a heavy hoisting plant, capable of working to a depth of 2000 feet. It is run by water, the power being communicated by means of rope transmission. The litigation between the Argonaut and Kennedy companies, in which the former company is plaintiff, is still pending. The geology of the Argonaut, and of the Kennedy Mine adjoining, will be treated in a separate paragraph following the description of the Kennedy Mine. There are 140 men employed.——Argonaut Mining Company of San Francisco, owners. J. B. Francis of Jackson, superintendent.

Argonaut Mill.—The rock is crushed in the breaker at the hoist and delivered to the mill bins, from which it passes by chutes to Challenge

feeders. The mill is in charge of Mr. B. Taylor. It has 40 stamps, which drop 7 inches, from 90 to 95 times per minute. No. 30 brass wire screen is used. The height of discharge is 8½ inches, which is kept as nearly uniform as possible by the use of several chuck-blocks. The capacity of the mill is somewhat variable, owing to changing characteristics of the ore, but it is about 3.25 tons per stamp daily. The quantity of water used in the battery also varies with changes in the ore. The apron plates have a grade of 2 inches to the foot, and the sluices 1⅝ inches per foot. These are dressed daily; the mill is cleaned up monthly.

Some experiments of an interesting character were made at this mill. The pulp was passed through a hydraulic sizer, the coarser material being sent to a Woodbury bumping-table, and the finer to Union and Woodbury belt machines. The coarse material treated by the bumper returned high values, and the fine material from the belts was of medium



PLAN OF GROOM DISTRIBUTOR - Argonaut Slimes Plant.

FIG. 8.

value. This probably represents the two classes of sulphide material found in this mine; a coarse, high-grade sulphide occurring in the quartz, and a fine, low-grade sulphide found in the slaty ores. Another experiment made at this mill was that of re-cleaning all the concentrates from fifteen machines by passing the concentrates of all these machines over one Union belt machine, with the result that 12 to 15 per cent of low-grade, silicious material, worth about $10 per ton, was segregated from the concentrates, which shows that previously a large quantity of material had been shipped away at a loss, as it contained less value than the cost of transportation and treatment. As the material thus segregated consists largely of quartz with gold, and a small amount of iron sulphide, it would seem that a considerable percentage might be recovered by grinding the sands in some sort of mill or pan with quicksilver.

The Argonaut Slimes Plant.—Mr. F. S. Groome has built and operates a slimes plant below the Argonaut mill—the pulp coming

directly from the mill to hydraulic separators, or spitzkasten, and passing thence to the distributers, the construction of which is illustrated in the accompanying sketch (Fig. 8). In size, the tables of the main plant are 8 x 16 feet. The sized pulp is distributed to three sets of tables, the coarse going to a set of three tables; the medium, which constitutes the larger portion of the material, passing to sixteen tables, and the finest material to a third set of three tables. The fall of the tables treating the finest material is $1\frac{3}{8}$ inches in 12 inches; the grade of the medium tables is $1\frac{1}{2}$ inches in 12 inches, and that of the coarse $1\frac{5}{8}$ inches in 12 inches; these grades are adjustable. The tables are covered with No. 8 canvas. Owing to the topography of the ground, it was not necessary to construct these tables in a series of steps lengthwise of the plant, as in the case of most plants of this character. The canvas is placed on the long lines of tables in a single piece, reaching the entire length of the plant, tacked at the edges, and then the entire floor is divided into a series of tables by tacking down 2-inch strips at regular intervals. The pulp is run for one hour on the canvas table; it is then shut off, and clear water turned on for about five minutes, when the sulphides are removed by means of a hose, usually taking one minute to the table. It takes one man forty-five minutes to make a complete round, and about fifteen minutes to look after the outside machines. In this plant, as at all others, at the foot of the tables is a double launder—one to carry the waste tailings, the other to carry the concentrates accumulating upon and washed from the tables. The concentrates from the tables are sent to an agitator, which re-sizes the material, the finer going to additional tables having a grade of $1\frac{1}{8}$ inches in 12, the coarser material going to a belt concentrator, the tailings from which are pumped to an outside table 24 feet in length, the overflow from which goes to a second set of three tables. The changes in the ore necessitate slight modifications in the treatment. About 125 tons of material are treated daily. Of the values that come from the mill, contained in the tailings, about 35 per cent is actually saved, 65 per cent escaping in the coarse quartz sand, the gold being evidently bound up in the quartz grains, which would require a finer crusher to liberate it; but attempts made heretofore to save this gold at a profit have proven abortive. It would seem, however, that if this material were crushed in a mill of proper construction, operated at a minimum cost of power, it might yet afford a small profit. In the construction of this plant, green redwood was employed. The foundations were firmly bedded, and the entire plant constructed with greatest care.

Kennedy Mine.—It is 1 mile north of Jackson, adjoining the Argonaut on the north. This property has been repeatedly described in former reports of the State Mining Bureau, but as it is one of the most prominent mines in the State, it merits further mention. The mine has

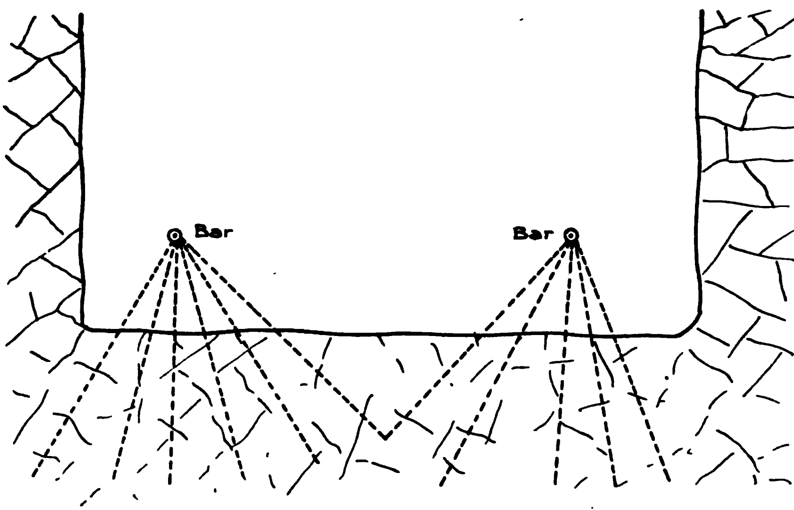
been worked continuously since 1885, when work was resumed at a depth of 750 feet, to its present depth of 2300 feet vertical. About 36,000 tons of ore have been crushed annually for the past fourteen years, at an approximate cost of $4.50 to $5.00 per ton, which includes the cost of mining, supplies, insurance, taxes, superintendence, purchase of property, dead work, and new work. This excessive cost is due largely to the heavy swelling ground and the cost of keeping the mine open. Since the last report, the two main shafts have been sunk several hundred feet, and a new vertical shaft has been started on the hillside about 1900 feet east of the old workings. This shaft, in January, had reached a depth of 915 feet; at this writing (June 12th), it is over 1300 feet deep. A cross-cut is being driven from the 2100-foot level of the Kennedy Mine to connect with the new vertical shaft. The general geological structure of the mine is referred to in a paragraph below, which also includes that of the Argonaut Mine adjoining.

The distribution of ore-shoots in the Kennedy-Argonaut vein is of considerable importance to miners along the Gold Belt, as in these extensive workings it has been shown that ore-bodies are not absolutely continuous, either longitudinally or in depth, and that workings can be driven over the top and along either side of an ore-shoot, and beneath it, in fact completely surrounding it, in a barren fissure. There are ore-shoots in the Kennedy Mine that do not approach within several hundred feet of the surface. On the 2100-foot level a new shoot was recently discovered which started on the west or foot wall (diabase), dipping at an angle of approximately 40 degrees eastward with a trend to the southward, which is contrary to the usual trend of ore-shoots in this mine. The main north shoot is wholly distinct and separate from that on the south, and it is also distinctly different in character. At the south end of the south shoot, several small veins come in from the hanging-wall side, uniting with the main fissure, and these gradually build up the large south ore-body.

The principal feature of interest at the Kennedy Mine at present is the new east shaft. The object of this expensive piece of work is to make the large bodies of low-grade ore exposed by development in the mine available at a decreased cost. This shaft has been sunk through hard greenstone at a rate approaching three feet per day. This was accomplished by the use of four machine drills, working three shifts. Arrangements were so made that the timber gang could work uninterruptedly while drilling was in progress below. The machines are set on two bars disposed near the end of the shaft, and after having been set in place a full round of holes is put in, from 28 to 35 in number, without taking down the machines. The holes are drilled from 5 to 6 feet vertically. The manner of pointing these holes is shown in the

accompanying diagram (Fig. 9). There is no hand-drilling, all work of squaring-up, etc., being done with machines. In this shaft 26 men are employed. The shaft is timbered throughout with 12 x 12 Oregon pine; sets 5 feet from center to center near the top, and in the lower portion 6 feet from center to center. The accompanying illustration (Fig. 10) shows the relation of the strike of the rocks to the position of the shaft. (Notice also the strike of rocks in the Oneida and Wildman shafts in this county—see Figs. 14 and 21.)

An unusual feature in the new Kennedy shaft, not often found in shafts sunk in hard rock, is the bridge used in timbering; this is illustrated in the accompanying sketches (Figs. 11 and 12). It was claimed by Mr. George W. C. Glass, who was in charge of this work, that this



SKETCH showing manner of placing MACHINE-HOLES in KENNEDY SHAFT.

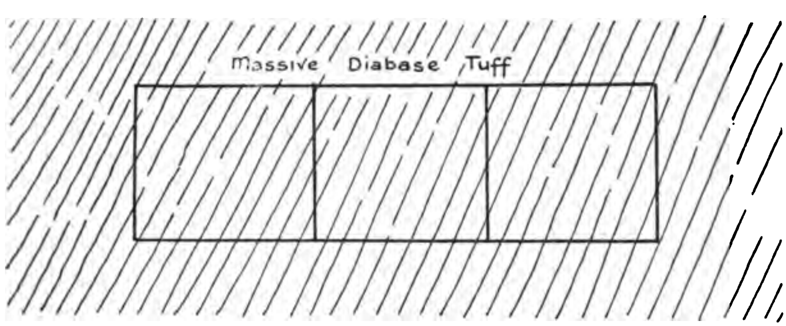
FIG. 9.

method of shaft-timbering greatly expedited matters and was less expensive than by the ordinary method. This manner of timbering shafts is not novel, but is usually employed in soft and not in hard ground; but as the bridges have been carried from top to bottom in this shaft, and as good headway has been made throughout, it is probable that this method has given entire satisfaction in this instance.

The Kennedy Mill.—This mill contains 40 stamps, and is in charge of Mr. Webb Smith. The monthly capacity is about 4,000 tons. The stamps drop 7½ inches 95 times per minute. The height of discharge is from 8 to 10 inches, three differential chuck-blocks being employed to keep these as nearly uniform as possible. The grade of the plates is 1½ inches to 12; 24-mesh brass wire screen is used in the battery,

formerly 30-mesh. The amount of water employed in the battery is variable, depending on the character of the ore. Cast-iron, chilled, manganese, chrome, and hammered steel shoes and dies have been used in this mill. The steel shoes and dies have given the best satisfaction; the iron shoes last about 50 days, the steel 95 days, the latter crushing about 340 tons of rock. The plates are dressed daily, and the general clean-up is made monthly. There are 24 Frue vanners in use. The sulphides collected on these machines are treated in the chlorination works at the mine, having a daily capacity of 3½ tons. The average saving is about 94½ per cent, and the cost is said to be $7 per ton, paying high salaries to experienced men.

The mortars used in the Kennedy mill were formerly of a wide type with double discharge, the rear discharge being closed for gold milling. These have all been replaced by narrow, lined mortars, designed by Mr.



SKETCH showing STRIKE of FORMATION across KENNEDY VERTICAL SHAFT.

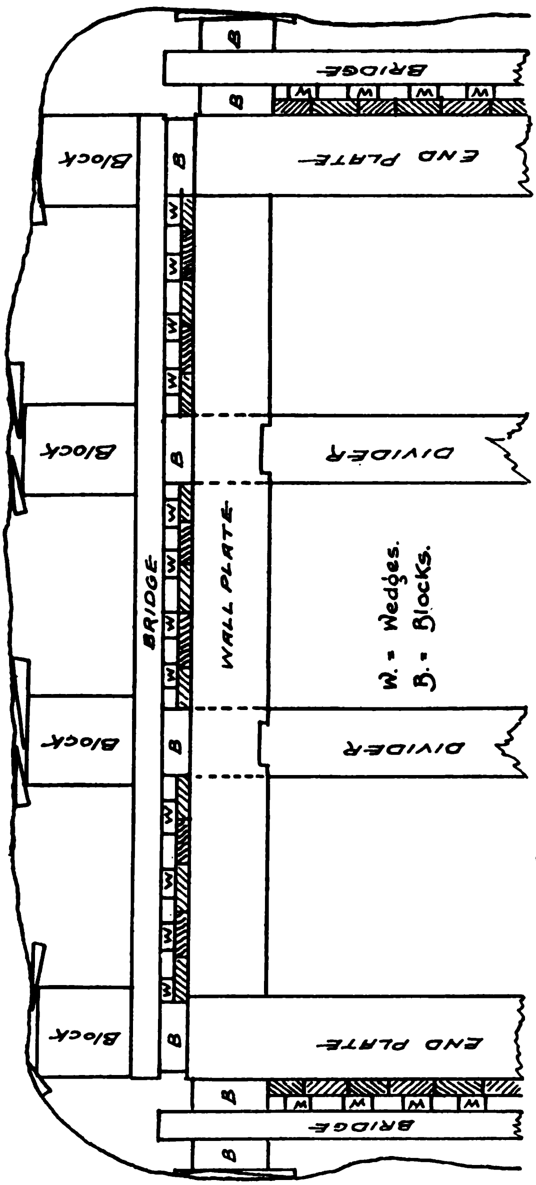
FIG. 10.

Webb Smith, the mill foreman. The mortars are lined throughout, and have a plate on the feed lip which may be replaced when worn. There are 150 men employed.——Kennedy Mining and Milling Company of San Francisco, owners. J. F. Parks, superintendent.

Kennedy Slimes Plant.—All the tailings from the Kennedy mill go to a slimes plant, one of the first built and successfully operated on the Gold Belt. The design is that of G. G. Gates of Jackson, who has carried the concentration of slimes to as near perfection as may be wished. Mr. Gates has also designed an end-shake belt concentrator which does splendid work on slimes. This machine is used in recleaning the concentrates from the canvas tables. The Gates plant is described at length in Bulletin No. 6, "California Mill Practices," by E. B. Preston. Since the publication of that bulletin, Mr. Gates has made no material change in the design of his plant or method of operating, although the plant has been entirely rebuilt. In its general features it is similar to that at the Zeila Mine.——G. G. Gates of Jackson, Cal., owner.

GEOLOGY OF ARGONAUT–KENNEDY VEIN.

In the Argonaut and Kennedy mines is found a perfect example of that class of mineral deposit known as, and called, a "true fissure" vein.



HORIZONTAL SECTION, one side of KENNEDY VERTICAL SHAFT, showing Bridges and Blocking.

FIG. 11.

By the term "true fissure" is meant a vein or fissure which cuts through rock formations of either similar or unlike character, wholly independent of either the dip or the strike of the rocks which form the walls of

the vein. Veins of undoubted fissure type do occur, however, which conform with strike or dip of the wall rocks, and in some instances with both.

That the Argonaut vein is persistent for thousands of feet in both strike and dip is abundantly proven in the extensive workings of the Argonaut and Kennedy mines, the connection of their levels at numerous points showing clearly the identity and continuity of the vein in these mines.

The geology of the vein is very simple and may be briefly stated. That geological horizon known as the "Mariposa Beds" (U. S. Geological Survey), which consists of deposits of clay slate and altered diabase

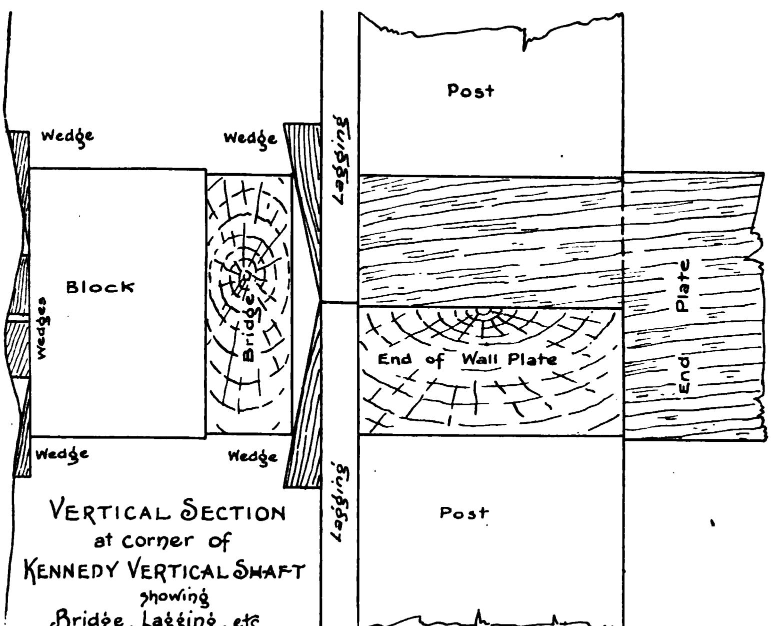


FIG. 12.

tuff, is found intruded by dike-like masses of diabase. These dikes are of varying width, and appear to have been thrust in from the northward, where, at a distance of 1000 feet or thereabouts, to the northward of the Argonaut shaft at the base of Reservoir Hill, the diabase seems to have almost wholly displaced the slates. To the westward of the most westerly of these slate strips is found a broad area of typical diabase (No. 18), mostly massive and granular, extending many thousands of feet to the northward and southward.

When in their normal position and condition, we find the slates of the Mariposa beds along the Gold Belt almost universally dipping to the eastward and striking a few degrees west of north. In the Argonaut

Mine local disturbances have resulted in folding, faulting, and crushing these slates, the degree of foliation and alteration appearing in proportion to the amount of crushing and shearing to which the rock has been subjected. Whether or not the cleavage of the planes of the slates are coincident with the planes of sedimentation cannot be determined, nor is it important. At Sutter Creek it is known that they are not. (For illustration, see Fig. 20, page 67.)

The diabase has also shared in this alteration from the same causes, namely, movement and fracture of the rock-masses due to tremendous compressive stress, resulting in a process of crushing and shearing of this hard, tough, granular rock, and its consequent alteration to splintery, schistose, and slaty rocks, with every phase of transition from granular normal diabase to chloritic schist and slate. (Amphibolite schist, U. S. G. S.) Diabase when so altered to a slaty condition forms the "gray slate" of the miners. The slaty structure developed in the tuffs is often so perfect that in some instances, particularly when found in the vicinity of the black clay slates where they have become blackened by metamorphosing influences, it is extremely difficult and often impossible to distinguish one from the other by their physical appearance. For a description of this type of formation see "Schists and Metamorphic Rocks," by G. H. Williams.

The vein can be followed continuously from its apex in the Argonaut claim to the lowest level of the mine without break or interruption of any kind. The apex or upper portion of the Argonaut Mine is wholly in massive diabase, which is found much decomposed for some distance on either side of the vein to a depth of several hundred feet, but for most part retaining its massive structure. (See Fig. 13.) In proximity to the vein, an alteration to a splintery or schistose condition may often be observed, and impregnations of pyrite are of frequent occurrence where such alterations are found. In the hanging-wall diabase near the surface are found numerous small veins and seams of quartz, some of which lie nearly parallel with the principal fissure plane, but the greater number have a westerly dip extending upward from the fissure into the hanging-wall.

Similar seams and vein-like sheets also occur in the foot-wall diabase, but usually in less number. These attendant sheets and veins of quartz are incidental to many veins elsewhere, and very frequently contain sufficient valuable material to entitle them to be included in the zone of pay rock together with the main fissure, when the entire zone of mineralization is, and very properly should be, considered as a single vein or lode. In making an examination of the vein structure and wall rocks in a raise extending upward from the 470-foot level to the adit (Pioneer tunnel) level of the Argonaut Mine, geological conditions were found to exist which at once determined the fact that the vein

occupies a "fault fissure," the hanging-wall having moved upward relatively to the foot-wall, constituting a "thrust" or "reverse" fault. There may possibly have been also a lateral movement along the fissure plane to the southward, striations found on the walls of the vein dipping to the northward tending to strengthen this belief. The amount of displacement as determined by measurement in the raise is about 125

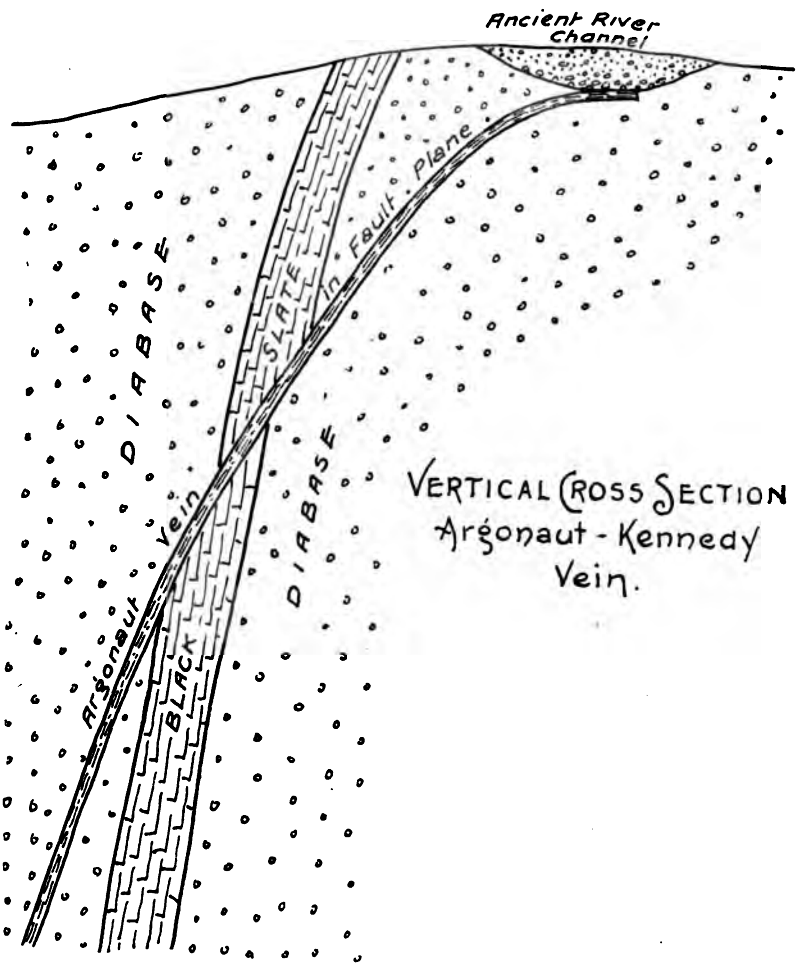
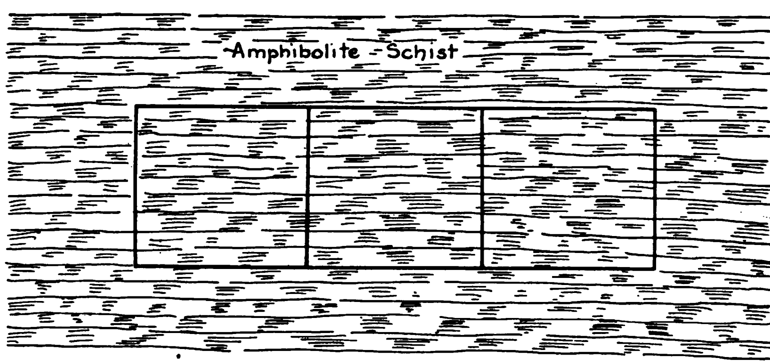


FIG. 13.

feet. The quartz occurs along this plane in a most persistent manner, and is rarely absent, even for a short distance. In width the quartz varies from 1 to 2 inches to upward of 30 feet. Where for a brief space quartz disappears in the raises above the 470-foot level, the gouge resulting from attrition caused by movement of these rock planes upon each other, which always accompanies this vein, clearly indicates the

plane of the fissure. In passing through these raises it may be noticed that where no quartz appears in the fissure on one side of the cutting, it may usually be found on the opposite side. No more conclusive evidence of a continuous vein than the fact that it occupies a fault plane could be desired.

It may be contended that this vein occupies a contact fissure, but the conditions above described and the abundant evidence found on the several levels of these mines, indicate clearly that any contact is of purely local character, and that the fissure is absolutely independent of it, for the vein does not conform for any considerable distance in either mine, in either strike or dip, to the contact planes of the black slates and the diabase, or the schistose and slaty rocks resulting from its alteration. The dip of the vein varies from a comparatively small angle at the apex to about 67 degrees from the plane of the horizon in



SKETCH showing relation of STRIKE of AMPHIBOLITE SCHISTS to direction of NEW VERTICAL SHAFT.- ONEIDA MINE.

FIG. 14.

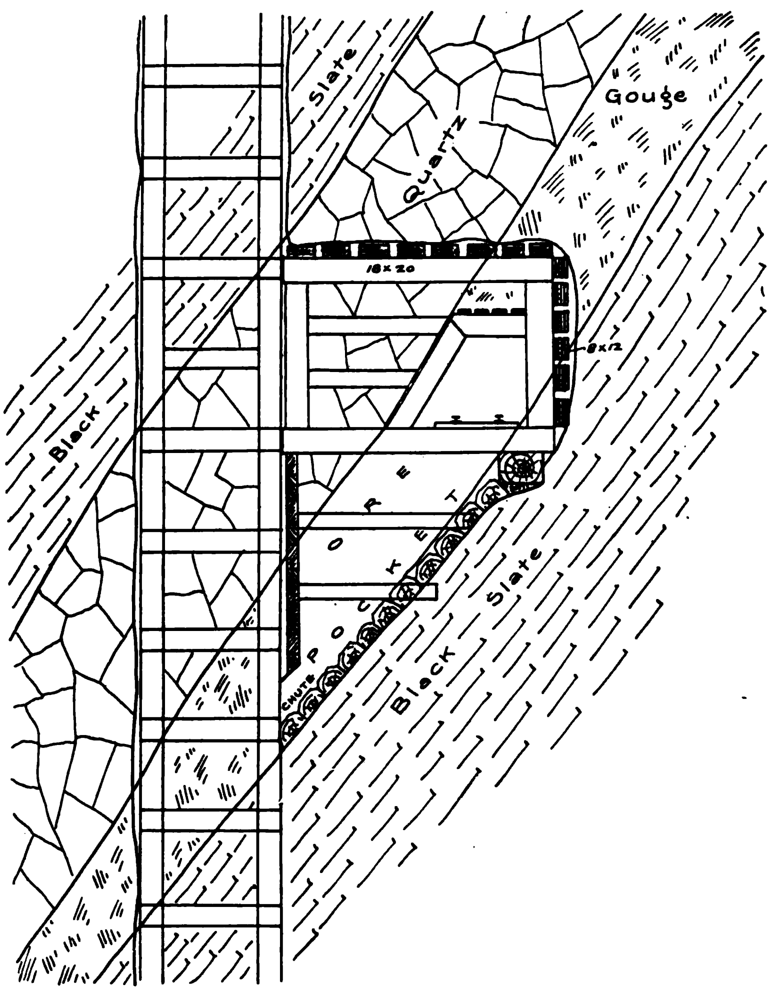
the lower levels, and in general at a somewhat less angle than that of the inclosing rocks.

Oneida Mine.—It is 1½ miles north of Jackson, adjoining the Kennedy on the north. Since the last report, a new vertical shaft has been sunk in the hanging-wall to a depth of 2050 feet. Ground was broken for this shaft January 13, 1896, and February 3, 1896, the shaft had reached a depth of 16 feet, when work was discontinued for the reason of bad weather. On March 9, 1898, the shaft had reached a depth of 1550 feet in two years and thirty working days, making a daily average of two feet. All this work was done by hand, excepting during a short time when machines were used, but their use was discontinued. This shaft was laid out to conform with the strike of the formation. (See Fig. 14.) In this respect it should be compared with the new vertical shaft of the Kennedy (see Fig. 10), and that of the Wildman at

ONEIDA MINE, AMADOR COUNTY.

THE CENTRAL EUREKA MINE, SUTTER CREEK, AMADOR COUNTY.

utter Creek (see Fig. 21). It is claimed that there is considerable dvantage gained in sinking the shaft at right angles with the strike of he formation or diagonally across it. The timbers employed in imbering this shaft were 12 x 12 and 14 x 14 inches. The upper porion, in soft ground, is closely lagged, but the greater part is without agging.

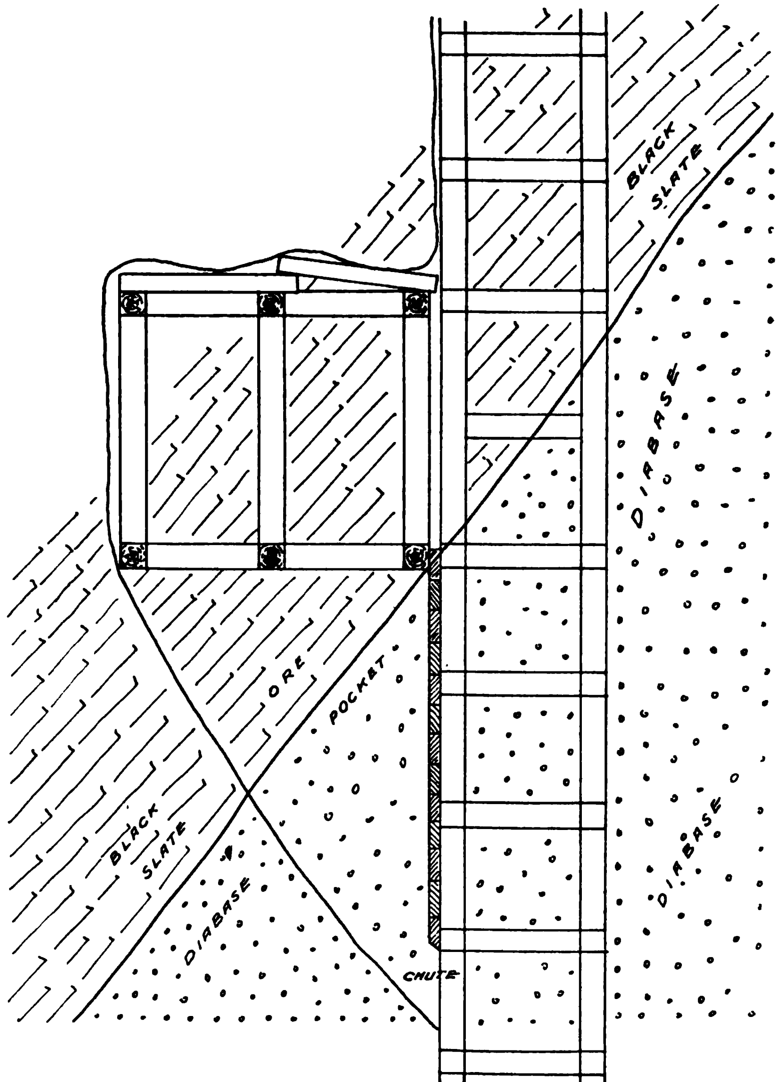


STATION AND VEIN - 1900 ft LEVEL. Oneida Mine.

FIG. 15.

Three ore-shoots have thus far been discovered in the mine, two of them near the shaft and the third north of it. The best ore developed is found on the 1500-foot level, although ore has also been developed on the 1700 and 1900 foot levels. The old incline shaft which was sunk by the former operators to a depth of 1350 feet has been cleaned

out, a great deal of it being found in a very bad condition. It wa probably one of the most expensive and difficult jobs of opening an ol shaft that has yet been found on the lode. The new vertical shaft an the old inclined shaft which will be extended downward, will b



STATION AND SHAFT. 2000 ft. LEVEL. Oneida Mine, Amador Co. CAL.

FIG. 16.

connected at various levels. The vein crosses the vertical shaft at the 1900-foot station. Here the hanging-wall is diabase and the foot-wall black tufaceous slate. At the station there is a heavy gouge on the foot-

wall side, and a large vein of fine-looking quartz. In the sump 50 feet below the 2000-foot level, and at least 50 feet west of the vein, a thin, flat seam of quartz was found in the diabase of the foot-wall, containing coarse gold. This is an unusual occurrence, or at least one not heretofore observed along the Lode. The method of timbering stations in the Oneida Mine is shown in the accompanying illustrations. (Figs. 15 and 16.)

A new 60-stamp mill is in course of construction at this writing, early in June. It will be necessary to elevate the ore by some means, probably an inclined tramway, from the shaft to the ore floor of the mill; this might have been obviated by sinking the shaft on a ridge a short distance eastward from the present site of the shaft. A large, expensive hoisting plant forms a part of the equipment of this mine. Forty-three men are employed.——The Oneida Gold Mining and Milling Company of West Virginia, owners. C. C. Derby of Jackson, superintendent.

Since writing the above the mill has been completed, and 20 of the stamps dropped early in September, thus adding another producing mine to those operating in Amador County.

South Eureka Mine.—This is one mile south of Sutter Creek, adjoining the Oneida on the north. The north shaft is down 1800 feet, the south shaft 330 feet, connected with the 600-foot level by a raise. This vein occurs in black tufaceous slates and greenstone schists. The ore-shoots trend to the northward and vary greatly in size. The vein is very much disturbed by faults and flexures, which are difficult to understand in the present stage of development of the mine. One perplexing peculiarity of this vein is the finding of rich masses of ore in a large vein of slaty gouge, which have no connection with any continuous ore-shoot. Recently (spring of 1900), some very good ore has been discovered in this mine. Another peculiarity of the ore-shoots is that they are richest in free gold at the north end, while the south end of the shoots are of much lower grade. It seems characteristic of these veins that while they are broad, the values are disseminated. In many of the mines of this county, where the veins exceed 10 or 12 feet in width, the best portion is found next to the foot-wall. In some cases from 1 to 10 feet of rock will be found above the average in grade, while the remaining 15 to 25 feet in thickness will be practically valueless, consisting principally of white, massive quartz. In this mine the superintendent has arranged an ingenious device for hauling timbers into stopes above the level. This consists of two sheaves set above in the raise, with one sheave at the main gangway. A rope is passed over these sheaves and a bucket attached at one end. This bucket is hauled up into the stopes, and a heavy timber attached to the opposite end of the rope down on the level. When the bucket is filled with ore it acts as a counterbalance, and the timber can be hauled up with comparative

ease. The mine is provided with a 20-stamp mill, run by electricity furnished by the Standard Electric Company. The hoist is run by water power under 180-foot head, the power being transmitted by means of a wire rope 600 feet long. There are 30 men employed, except when the mill is running, when there are from 60 to 70.——South Eureka Mining Company, owners. J. F. Parks of Jackson, superintendent.

Central Eureka Mine.—This property adjoins the South Eureka on the north, half a mile south of the town of Sutter Creek. This mine, after an idleness of many years, was reopened by a new company in the fall of 1895. There were several shafts on the property at that time, the deepest being the south shaft, down 700 feet. Since that time the shaft has been continued to a depth of 1700 feet and a number of long levels opened. At about the 1000-foot level, several narrow and short shoots of high-grade ore were developed. As depth was attained and levels driven out, these ore-shoots were found to lengthen and increase in width while maintaining their values, until in the deepest portion of the mine the several short shoots have united, forming a single long shoot. At this writing (January, 1900), the Central Eureka Mine is one of great promise. The vein is the most simple in geological structure of any extensively developed mine on the Central Lode. It consists practically of a single fissure cutting in strike and dip the black tufaceous slates and amphibolite schist which form its walls. The mine has certain peculiarities which are noticeably persistent. One of these is the firmness and regularity of the hanging-wall. The wall is not absolutely straight in strike, but rolls more or less in a series of long swells. The gouge, which is always found on the foot-wall side, also has a sinuous course, swinging toward and away from the hanging-wall. When at some distance from the hanging-wall little or no ore occurs in the fissure, but upon its approach to the hanging-wall the long lenticular masses of quartz which constitute these ore-bodies, begin to form. Another feature of the vein is found in the increasing mineralization of the rock forming the hanging-wall upon nearing an ore-shoot. Although at the time of my visit no cross-cuts had been made in the hanging-wall country from the lower levels of this mine, there is little doubt that considerable portions of the mineralized zone of the hanging-wall will be found to make payable ore, although of comparatively low grade. A considerable quantity of the ore taken from the shoots above described has been milled, returning an average of about $70 per ton. The hoist is run by water power. A 10-stamp mill has been completed and is in operation. The mill has an extension for 10 additional stamps. In September the shaft had reached a depth of 1845 feet, and the vein is from 1 to 12 feet in width between the 1400 and 1800 levels. A new hoist is being put in, and the mill, rockbreaker, and exhaust fan are running by electricity.——Cen-

THE MAHONEY MINE, SUTTER CREEK, AMADOR COUNTY.

TIMBERING IN CAVING GROUND, MAHONEY MINE, AMADOR COUNTY.

tral Eureka Mining Company, owners. W. R. Thomas of Sutter Creek, superintendent.

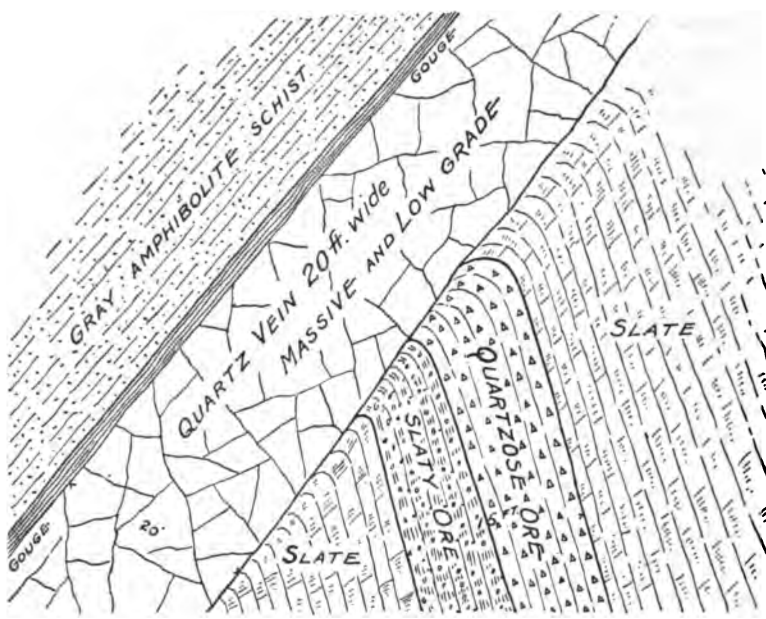
Wildman-Mahoney Mine.—This is at Sutter Creek. The property consists of the Wildman, Mahoney or Hector, and Stewart claims, also the Waechter ranch to the eastward of these mines on which a new vertical shaft is being sunk. The development at present is chiefly confined to the Wildman and Mahoney claims, which join and are operated through two inclined shafts. The Wildman is 1300 feet deep, the Mahoney 1000. The 1000-foot level of the Mahoney is equivalent to the 800-foot level of the Wildman. The ore-bodies of these mines, both great and small, appear to be confined to a definite zone lying between two reefs of Mariposa clay slates, although these latter appear not to be directly associated with the ore-bodies themselves. The zone included between the clay slates consists principally of amphibolite schist and tufaceous black slates. In the southern portion of the Wildman Mine the ore zone is confined to narrow limits, but going northward it broadens, and in the Mahoney claim the vein splits into two sections, the east

Good ore lying each side of a 3 ft Gouge in Wildman Mine

FIG. 17.

branch going into the Stewart claim and the west into the Lincoln. The idea seems to prevail that the mines of the Gold Belt of Amador County are simple fissures, which are easily followed and are regular and persistent. Just the reverse, however, is usually the case, as the ore-bodies are found disturbed by faults, and often contorted and displaced in a most puzzling manner. On the 300-foot level of the Mahoney Mine one vein follows a gouge 4 feet wide, on the hanging-wall of which the ore continues for a distance of 300 feet; going southward for some distance the ore loses its value, but undergoes no physical change that is noteworthy. Noticing that the gouge contained small masses of good ore, from 20 to 400 pounds in weight, Superintendent Ross cross-cut into the foot-wall and found good ore in the opposite side. (See sketch, Fig. 17.) This was the only place known, up to that time, where pay ore was found in the gouge. The ore found on the foot-wall side of the zone was 15 feet wide, but its length has not been determined. These ore-shoots are known to overlap 25 feet at least, and probably much more. Another instance of irregularity was noticed in the Mahoney Mine 30 feet

above the 900-foot level, where is found what appears to be a displacement of a banded vein 15 feet in width, which, together with the inclosed slates, is contorted and cut off abruptly, the sheared end abutting against a solid vein of quartz 20 feet in thickness. (See Fig. 18.) The continuation of this faulted vein has not, as yet, been found above. The slaty material found underneath the banded vein is also gold-bearing in paying quantities. A stope on the 900-foot level of the Mahoney follows a well-defined, persistent wall for a long distance. This stope is 25 feet in width. A fissure crosses the ore-shoot at an angle of 65 degrees, dipping south. Beyond this was found the above described disturbance.

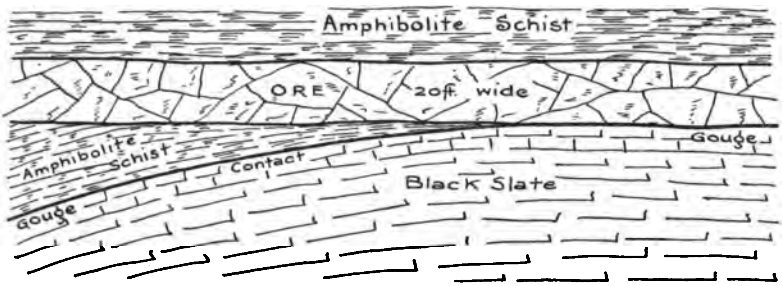


FAULT on 900 ft. LEVEL of the MAHONEY MINE, Sutter Creek.

FIG. 18.

On the 1000-foot level of this mine, a stope follows what appears to be the wall above described, with large ore deposits on either side of the wall. The wall takes a slight flexure to the west, and the ore follows the wall on the foot side, while that previously followed on the hanging-wall side bears more to the east, and a slate horse separates them. In the main level, the drift continues south, and a new ore-shoot comes in from the east or hanging wall. A diamond-drill hole run west, here passes through 6 feet of slate and cuts 3 feet of quartz, which is succeeded by 22 feet of slate and 6 feet of ore. This probably represents the two branches of the divided vein. The diamond-drill hole continues for a distance of 204 feet, where it cuts a vein of good ore 13 feet

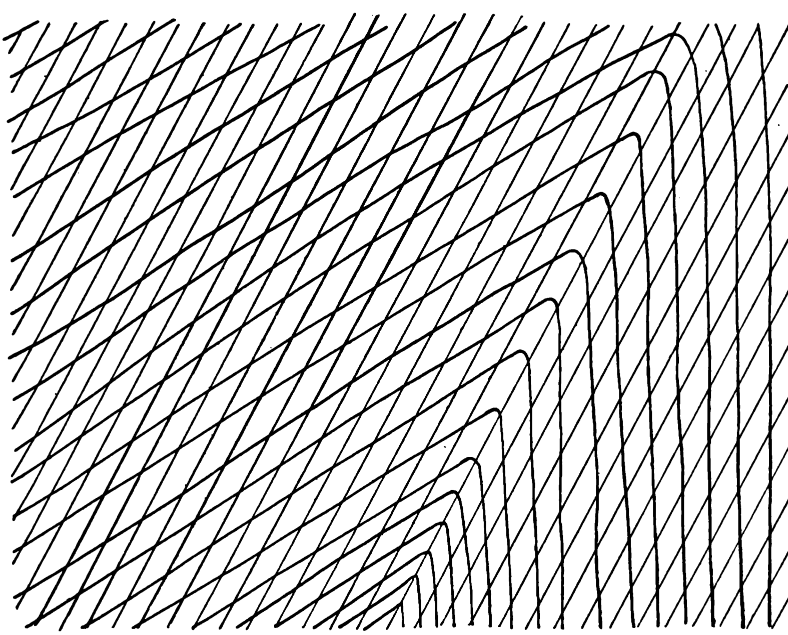
thick. This may be the downward extension of the ore dipping westerly on the level above, though such a thing is far from certain. In the



SKETCH OF VEIN IN WILDMAN MINE.
showing independence of Vein and Contact.

FIG. 19.

Wildman Mine, on the 800-foot level, is a 24-foot ore-body on the slate foot-wall. On the 1000-foot level of the Mahoney, what is evidently

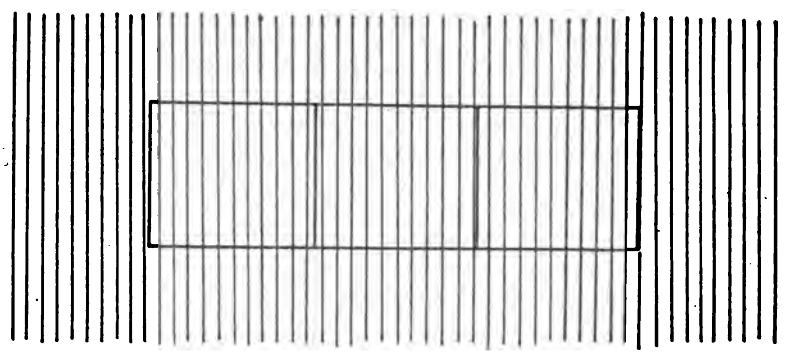


SLATY CLEAVAGE - Developed by pressure in folded Strata of MARIPOSA BEDS AT Sutter Creek, Amador Co. CAL.
HORIZONTAL SECTION
FIG. 20.

this same ore-body is developed, but it lies 23 feet east of the slates (Fig. 19). These irregularities are only a few of those which occur

throughout this extensive property, and are simply mentioned to illustrate the peculiarities and irregularities of the ore-deposits. A complete description of the mine, taken by levels, would fill a good-sized volume. The Wildman-Mahoney Mine labors under great disadvantage in being obliged to work through the old inclined shafts, that of the Wildman Mine being particularly bad, and the cause of what would be otherwise unnecessary expense. The completion of the new Emerson shaft, below described, will remedy this trouble, and the large bodies of ore, too low-grade to pay under existing conditions, can then be worked at a profit.

Fig. 20 illustrates the contortion of slates and the subsequent development of slaty cleavage in Mariposa beds at Sutter Creek. The sketch is of an area 20 feet square.



SKETCH showing Relation of Strike of Formation to Wildman Shaft.

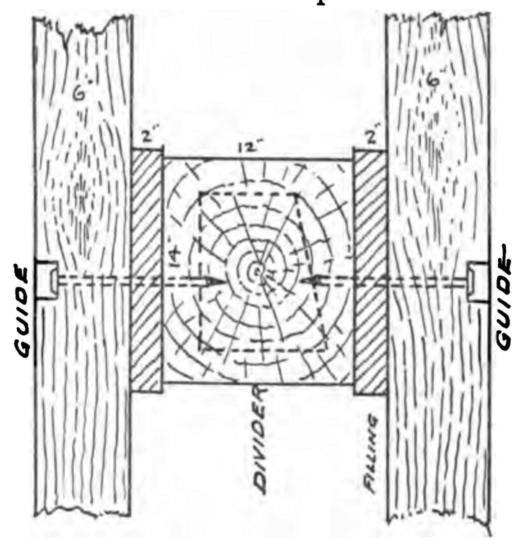
FIG. 21.

The Emerson Shaft.—The new, or Emerson, shaft, as it is called, is vertical, and is being sunk nearly 1000 feet east of the present Wildman inclined shaft. It is calculated that it will cut the Wildman vein at a depth of between 2300 and 2400 feet. It is difficult to give the exact depth, as through this section the lode flattens more or less in depth. It is now down over 700 feet. The ground passed through is diabase and diabase tuff, with some very hard gray slate (altered diabase), an occasional seam of black slate and stringers of barren quartz. The excavation outside of timbers is 8 x 20 feet, and is made across the stratification of the country—that is, the length of the shaft is east and west. (See Fig. 21.) Timbers used are all selected spruce, 12 x 14 inches, framed in the usual Comstock style, with the following exceptions:

First, the wall-plates are placed with the 12-inch side vertical, and the dividers with the 14-inch side vertical. A dap is cut ½ inch deep in the wall-plate, top and bottom, for the center posts, which leaves 1½-inch footing and heading for the posts, as the 14-inch side or end of the divider comes against wall-plate and posts, thus giving more strength

to the wall-plate and a better footing for the posts than would be the case if the divider were of the same width as the wall-plate.

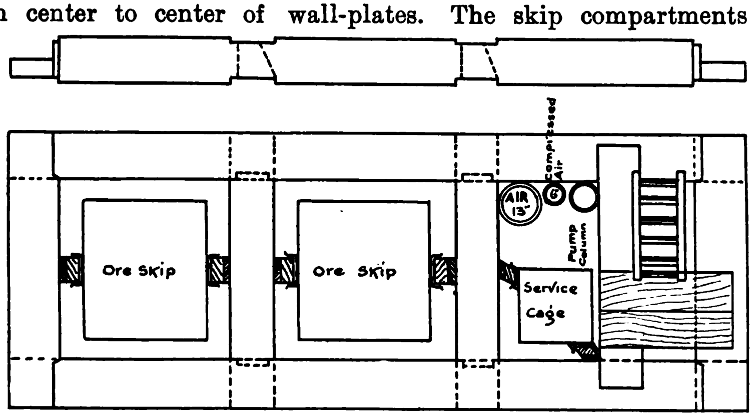
Second, as seen in sketch of divider (see Fig. 22), a 2-inch filling piece is inserted behind each guide, which gives 4 inches to work on (in keeping guides true) in case of a squeeze in the shaft.



SECTION OF GUIDES AND DIVIDER
Showing Filling Piece - Wildman Shaft.

FIG. 22.

The sketch of section of shaft (Fig. 23) shows a small "service cage" in the pump compartment for the use of foreman and pumpmen. It is to be run open on two sides, to facilitate the handling of long lengths of pipe. All of the pipes are set on the side of the shaft opposite this cage. The ladders are each 15 feet long, inclined over each other, there being a landing at the end of each ladder. The shaft sets are 4 feet apart, or 5 feet from center to center of wall-plates. The skip compartments are



ARRANGEMENT OF TIMBERS - WILDMAN SHAFT.
FIG. 23.

$4\frac{1}{2} \times 4\frac{1}{2}$ feet, and the pump and ladder compartments $4\frac{1}{2} \times 5$ feet. The wall-plates and ends of dividers are so framed that the dividers are driven up into place instead of down, which prevents their being knocked out by blasts.

It is the intention to use skips that will carry 3 tons of ore at a load, making total weight of load (including cable and skip), starting at a depth of 2500 feet, about 6 tons. Foundations of stone and cement for permanent headgear have been built from bedrock to the level of the collar of the shaft. The temporary hoist and gallows frame now in use

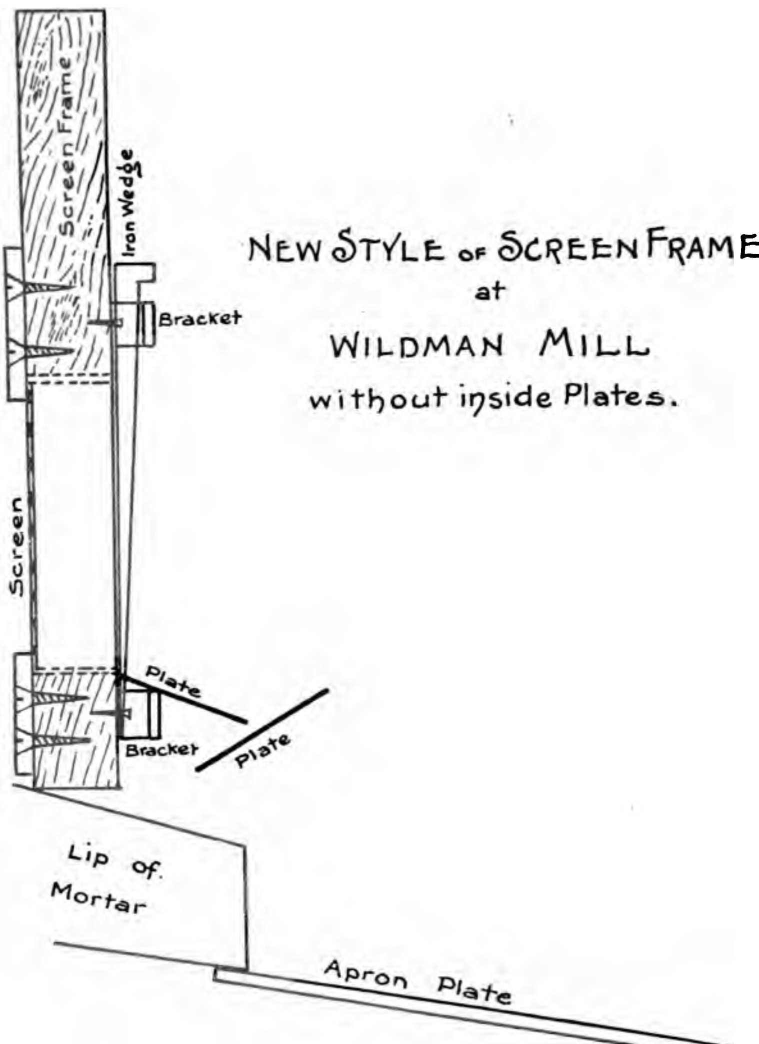


FIG. 24.

at this shaft is so constructed and arranged that the permanent steel head frame can be erected over the shaft without interfering with the progress of work. The design of the proposed steel headgear is by E Chodsko, of San Francisco. If erected this year it will be the first of its kind in California.

The Wildman Mill.—The mills of the Wildman Company are operated with as great care as any in the State, and merit a detailed description. There are two mills, each of 40 stamps. In the Wildman mill the stamps weigh 850 pounds; these drop from 7 to 9 inches 96 times per minute; the guides are of iron; the height of discharge is 7½ inches, regulated by chuck-blocks, having a difference of ½ to 2 inches in height. A No. 2 punched tin screen is used. The capacity of the mill had been about 145 tons per day under the above conditions, but the height of discharge has been lowered not to exceed 6 inches for the purpose of experimentation. This will have a tendency to increase the capacity of the mill. The outside plates have a grade of 1½ inches to the foot.

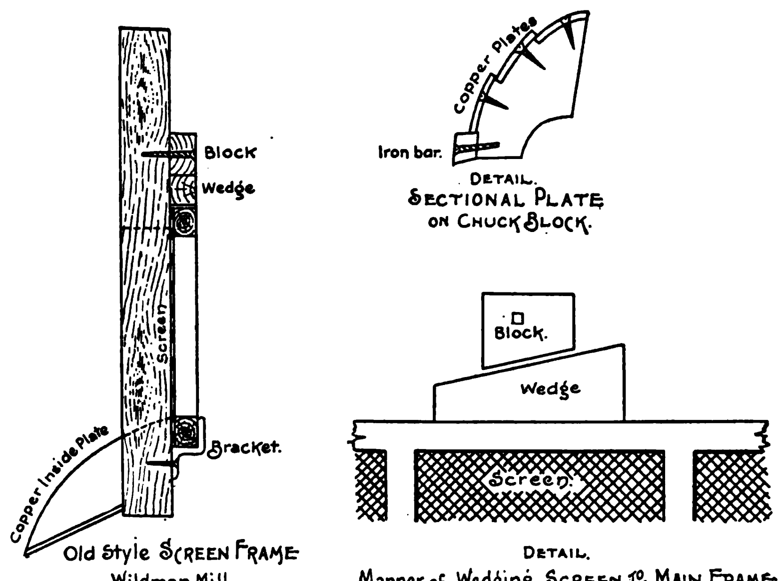


Fig. 25.

There are 14 Frue vanners and 2 Triumph concentrators in use. The ore contains about $1\frac{7}{10}$ per cent sulphurets, which are shipped to Selby's. They formerly used 11x48 inch No. 24 Russian iron and cold rolled steel screens, diagonal slot. Of these the steel screens proved the most durable. They now use a No. 2 punched tin screen having 225 holes to the square inch. These apertures have a slightly greater diameter than the slot of the No. 24 screen. Formerly the screen was secured flush with the outside of the frame, which was provided with an inside plate. The screen frames are now arranged as shown in the accompanying drawing (Fig. 24). The former method is shown in Fig. 25.

The Hector or Mahoney Mill.—In this mill there are 40 stamps, which weigh 950 pounds. The height of the drop is from 7 to 9 inches 96 times

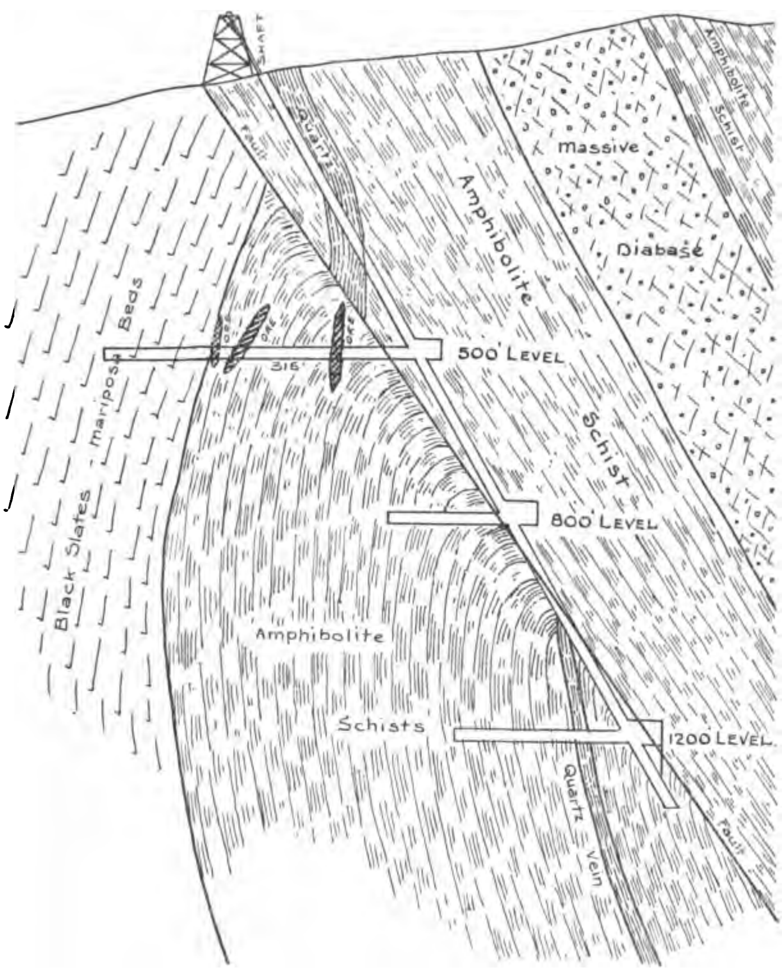
a minute. The height of discharge was formerly 6½ inches, but is now from 3½ to 4 inches, being adjusted by differential chuck-blocks. The Globe Iron Works guides are in use. A No. 2 punched tin screen is used, the capacity being 146 tons per day. Chrome-steel shoes and dies having 8½ inches diameter are used. There are 16 Frue vanners in the mill which concentrate the sulphides, these constituting $1\frac{9}{10}$ per cent of the rock. In the Hector mill the pulp falls from the batteries onto a 4-inch plate and drops to a second plate pitching backward, falling on the lip of the mortar below, in front of which is a 5-inch plate with a ¾-inch drop to the first apron plate 28 inches wide. The inside plates have been taken from the mortars and every effort made to increase the capacity of the mill, while giving the most careful attention to outside amalgamation. Below the first apron plate, the pulp falls into a trough 3 inches wide and 4½ inches deep, discharging through ten 1-inch auger holes, then to a 3-inch board and onto plates 24 inches square, arranged in double parallel series. The pulp passes by two drops to two other sets of plates, at the foot of which is a mercury trap. Below the trap are sluice plates with three drops of 2 inches each. These plates are 12 feet long, at the lower end of which a second trap is arranged, from which the pulp goes to the vanners. 165 men are employed in the mines and mills.——The Wildman Gold Mining Company, owners. John Ross, Jr., of Sutter Creek, superintendent.

Lincoln Mine.—It is at Sutter Creek. This property was worked in early days, a shaft being sunk 807 feet. To a depth of 350 feet, or thereabouts, it is said that the mine paid handsomely. At that depth a fault intersected the vein and all trace of it was lost. The present company re-opened the mine in the latter part of 1898. The old shaft was repaired, the workings cleaned out, and sinking resumed in February, 1899. The shaft is now 1260 feet in depth. On the 500-foot level a drift has been extended several hundred feet, and a cross-cut run both east and west about 200 feet north of the shaft. That portion east of the main gangway is in tufaceous slate and diabase, and that to the westward passes through the black tufaceous slates, and then through a broad zone of hard, amphibolite schist, to the black clay slates of the Mariposa beds 315 feet west of the gangway. In this cross-cut are exposed three ore veins, one of which has been drifted for a distance of 168 feet. This vein is 110 feet west of the gangway. A second vein is encountered 135 feet farther west. This vein is from 6 to 20 feet wide, and carries a satisfactory grade of pay rock consisting of quartz and amphibolite schist with disseminated auriferous iron sulphide and free gold. It has been developed by a drift 200 feet long. The third vein lies about 70 feet to the westward of the last-mentioned vein, near the contact of the amphibolite schist and the clay slate of the Mariposa beds. It has not been developed as yet. As there appeared to be

LINCOLN MINE, SUTTER CREEK, AMADOR COUNTY.

THE BUNKER HILL MINE, AMADOR COUNTY.

some doubt as to what had occurred at the 350-foot level, when the mine was formerly operated, a careful examination of an old abandoned level extending from the shaft at 400 feet from the surface was made by Superintendent Voorheis and the writer. An investigation at this point discovered the fact that a fault fissure had dislocated the vein.



CROSS SECTION - LINCOLN MINE - Sutter Creek - At Main Shaft -

FIG. 26.

The fault strikes nearly parallel with the vein, dipping to the eastward at an angle of about 58 degrees, and appears as a zone of fracture and movement 4 to 6 feet in width. To the eastward of this fault plane the schists and slates and the vein itself all have an easterly dip. Underneath the fault plane, however, the entire country—schists, greenstones,

slates, and veins—dips strongly to the westward. In the west cross-cut north of the shaft on the 500-foot level, and in a west cross-cut south of the shaft on the same level, this condition is clearly in evidence. A cross-cut run westerly from the shaft at the 650-foot level shows the formation to be still pitching to the westward, though in a cross-cut at the 800-foot level it is standing nearly vertical, and on the 1200-foot level the formation has assumed nearly its normal easterly dip in the neighborhood of the shaft. On this level, at the face of the cross-cut 275 feet west of the shaft, it has a slight westerly dip. These workings show that the entire formation lying to the westward of the fault plane has been contorted from its normal position, having a westerly instead of an easterly dip, although as depth is attained the formations appear to assume their normal positions. The sketch (Fig. 26) illustrates the structural features of the Lincoln Mine. All the evidence obtainable leads to the belief that the rich vein worked from the surface slipped downward along the fault plane, and that its further extension downward must be sought in the country lying to the westward of the shaft, and it is the belief of the writer that the cross-cuts on the 500-foot level have intersected the vein which was dislocated by the fault at the 350-foot level.

The mine is well equipped with steam hoist, air-compressors, machine shop, and other accessories, but has as yet no mill.

In recovering the old Lincoln shaft, the settling of the ground had forced the shaft out of line, which necessitated the removal of a large amount of ground from the hanging-wall side of the shaft. To keep it in alignment this space was timbered in square sets, the number of the sets varying with the distance from the shaft to the solid ground. This has not been found to give any trouble.

In swelling ground, such as is found in this mine and many others in this county, experience has demonstrated the advisability of cutting large stations and placing sets outside of the main station sets; lagging openly—leaving spaces 8 to 10 inches between the lagging, which preferably, should be light. These light lagging, under pressure from the swelling ground or from a squeeze, will bend and eventually break thus giving sufficient warning before material damage results to the main members of the set. The open spaces are useful in cutting out and removing the swelling ground, and the lagging may be removed if necessary, but the main timbers will only occasionally require resetting or renewing. There are 24 men employed.——The Lincoln Gold Mine Development Company of San Francisco, owners. E. C. Voorheis, superintendent.

Mutual Mine.—On the summit of the ridge between Sutter Creek and Amador City. A vertical shaft has been sunk on this property to a depth of 400 feet (March 1, 1900). Cross-cuts are being run to prospect

two veins, one of which lies in the black slate on the hanging-wall side of the shaft, and the other in greenstone schist on the foot-wall side. The hanging-wall vein has been reached and good ore found in a drift on the vein. In some surface workings very good ore was taken from the foot-wall vein. The mine has a substantial steam hoist, and is otherwise well equipped for prospecting. There are 15 men employed. ——Mutual Mining Company of San Francisco, owners. S. R. Porter of Sutter Creek, superintendent.

Baliol Mine.—This is 1 mile east of Sutter Creek, and comprises a number of claims on patented agricultural lands, and covers a series of veins in amphibolite schist. An inclined shaft has been sunk to a depth of 750 feet, with levels at 200, 300, 500, and 700 feet and stations at 400 and 600 feet. In a cross-cut run easterly from the shaft, a distance of 380 feet, four of the veins have been intersected; No. 1, the foot-wall vein, is cut at a distance of 110 feet from the shaft, and is about 12 feet wide; No. 2, 39 feet farther east, is from 7 to 17 feet wide; No. 3, 35 feet eastward, is 60 feet wide; and No. 4, 74 feet beyond the last, is 6 feet wide. Since February, 1900, a cross-cut east from the 500 station has discovered higher grade rock than any found in the veins above mentioned. All stoping is done by means of machine drills. The diamond drill has been used with good results in this property, bore holes driven to the eastward having cut good-sized bodies of ore some distance from the main development of the mine. A large amount of ore has been stoped from three large open cuts, all showing a similar character of ore. The large veins resemble, somewhat, those of the Utica-Stickle mines of Angels. The foot-wall is diabase tuff, slightly schistose. The hanging-wall is also of this character, but farther east are intrusions of granitic rock. A granular-dike rock of light-gray color, much silicified, and containing about 2½ per cent sulphurets, constitutes, together with vein-like masses of quartz, the principal ore-shoots in this mine. Occasionally copper sulphide and arsenical sulphide ores are found. The property is equipped with a 40-stamp mill, the stamps weighing 1100 pounds, dropping 5 inches 102 times a minute. No. 35 mesh punched tin screens are used, the discharge being from 4½ to 5 inches high. The capacity of the mill is 4½ tons per stamp. Chrome-steel shoes and cast-iron dies are in use; one shoe will outlast three dies, the life of the shoe being 112 days. Risdon vanners are used for concentration. There is no canvas plant. The plates are 60 inches by 24 feet, with a 1¾-inch drop. The apron plates are on carriages, and may be rolled away from the front of the battery when necessary to clean up. The plates are dressed as often as necessary—usually twice in 24 hours. The proportion of free gold is variable, constituting from 40 to 70 per cent of the values. The sulphurets are shipped to Selby's. The mill and air-compressor are run by water power. The hoist is operated by air, the compressor being located at the mill.

It has an automatic hydraulic governor, made at the Knight foundry of Sutter Creek. This maintains a pressure at 80 to 100 pounds. The compressor is driven by a water-wheel under 452 feet head. There are 100 men employed.——The Western Gold Mining Company, owners. W. H. Storms of Sutter Creek, superintendent.

Potazuba Mine.—It is situated 1½ miles east of Sutter Creek, adjoining the Baliol on the west. The shaft has been sunk to a depth of 500 feet on the vein, with a sump 40 feet, by means of a small steam hoist. Levels have been run at 100, 200, and 350 feet; the shaft and levels are on the vein, which varies from a few inches to 12 feet in thickness. The foot-wall portion of the ledge has proven very rich. At the Zeila, Wildman, and Baliol mills were made several runs of the rock from this foot-wall strip, which have produced about $15,000, averaging about $25 per ton, some of the ore running as high as $100 per ton. The hanging-wall portion of the vein is low grade. The mine is in the hands of a local company, which has spent $40,000 in its development. Heavier machinery will be required to sink to greater depth. At present the mine is idle from lack of funds to properly equip it, although it is expected to resume operations some time this year.——The Potazuba Company of Sutter Creek, owners. W. J. McGee of Sutter Creek, secretary.

Treadwell & Guliana Mine.—This is 8 miles east of the town of Sutter Creek. There are two veins in the property, on one of which, the Treadwell, there are two tunnels, one 700 feet, the other 300 feet in length; besides which there are numerous superficial cuts. The vein is from 1 foot to 12 feet wide, and has produced some high-grade ore. The Guliana vein was discovered in the bed of Sutter Creek, where it is 3 feet in width, showing free gold. There is a 30-foot shaft and a short tunnel on this vein. The mine is idle. The mill which was formerly on the property is dismantled. The mill contained 6 stamps, and was operated by water under 150-foot head with a 10-inch pipe-line. This did not apparently afford sufficient power to run the mill, and it was consequently shut down. Several years later, it is said, it was discovered that in some manner a piece of scantling had gotten into the pipe-line, descended by suction to the nozzle, clogging it, and reducing the power to the extent described.——M. D. Nixon et al. of Sutter Creek, owners.

Free American Mine.—This is 6 miles east of Sutter Creek, on a small vein of high-grade rock in Calaveras formation. In one place it is stated that the vein is 6 feet wide, and that the rock will run $25 per ton, and at the bottom of the shaft the vein is 8 feet wide in good milling ore. The shaft has been sunk to a depth of 110 feet near Sutter Creek, and a drift extended out under the creek along the vein, with the

result that the mine was flooded, the surface water probably coming directly from the creek. The property was provided with both water and steam hoist, a jackhead pump and a steam pump, both of which were operated as vigorously as the power would permit, in addition to bailing with the skip at the same time; but this combination failing to lower the water in the shaft, operations had to be abandoned. A light 10-stamp mill forms a portion of the equipment of the mine.——Wilfred Dennis of Sutter Creek, owner.

South Spring Hill Mine.—This property adjoins the Keystone on the south, and is in many respects similar to it geologically. After an idleness of about seven years, operations were resumed in June last, and at this writing (June 10th) the mill is about ready to start. It is said that good ore is being found at the north end of the mine.—South Spring Hill Mining Company, owners. John R. Tregloan of Amador City, superintendent.

South Keystone Consolidated Mine.—This is half a mile south of Amador City, adjoining the South Spring Hill. It is in the prospective stage.—J. A. McIntyre of Amador City, owner.

Keystone Mine.—This is at Amador City, and is one of the most extensively developed mines in the State. There are probably not less than 10 miles of underground workings in this famous old mine; but all work at present is confined to points above the 1000-foot level, although the shaft is 1575 feet in depth. The formation at the Keystone Mine consists of diabase tuff, tufaceous slates, and the clay slates of the Mariposa beds, the latter lying west of the principal veins. To the west of these clay slates, massive diabase is again found. The principal veins, however, are those occurring in the tufaceous slates. The main vein occurs along a fault plane, which has a variable dip from 35 to 65 degrees to the eastward and extending more than 2000 feet in a remarkably straight course. On the hanging-wall side of this fault plane occurs immense masses of diabase material and quartz, which in places is more than 100 feet in width. Considerable portions of this constitute payable ore, although there are large quantities which it will not pay to mine. This great, massive vein forms the hanging-wall of a banded slaty vein, which has produced a large amount of pay rock south of the main shaft. Between the 400 and 600 levels on this vein an immense stope covering a superficial area of 20,000 square feet has been cut, the vein in places being 25 feet in width. There are few timbers and but one or two pillars in this great stope, which has been open for years, which indicates how well this ground stands without artificial support. This is probably the largest open stope on the Gold Belt. This was being filled as rapidly as possible during my visit, in order that the large amount of ore known to lie in the overhanging (so called) wall may be mined

so as to reduce the width of the mortar 2 inches, by placing the screen flush with the main frame. The stamps have been speeded to 100 drops a minute; the discharge has been lowered, and closer attention is being given to outside amalgamation. The apron plate has been widened to 60 inches for a length of 16 feet, and the grade of these plates has been reduced to 1¾ inches per foot. No water is added outside the batteries, as in all the others, and the inside-battery water has been reduced to the lowest possible amount. The lowering of the discharge would probably have increased the capacity of the mill, but the decrease in the amount of battery water has a tendency to retard discharge. The capacity of this battery is about the same as that of the other batteries, but as a result of these changes, the tailings have shown a marked decrease in value, and it is the intention to adapt the entire mill to these changes. A new chuck-block with corrugated copper plate (see Fig. 27) has been introduced in this mill.

Bunker Hill Mine.—It is 1½ miles north of Amador City. This property is a consolidation of the Bunker Hill and May Flower. On it is a shaft in the May Flower 350 feet in depth. The old shaft of the Bunker Hill was sunk to a depth of 800 feet; it had been closed for a number of years when it was re-opened in the latter part of 1899. The upper portion of the shaft was badly caved, which required a great deal of work to recover. A cross-cut tunnel was driven some years since near the base of the hill to connect with the old May Flower shaft at a station, and a branch driven beyond in the direction of the Bunker Hill. This latter has been continued to the Bunker Hill vein, it being the intention to drain the mine of surface water through this tunnel. There is also a shaft 400 feet deep on the south end of the property. The hanging-wall of the vein is a fine-grained grayish rock (No. 16), in places carrying considerable finely disseminated iron sulphide; this rock is diabase tuff, greatly altered. The slates found in the foot-wall are the result of alteration of tufaceous diabase, and bear the characteristic pitted marks which distinguish this class of slates in Amador.

In its early history, the Bunker Hill is credited with a production of about $1,000,000 down to the 700-foot level. The shoots have a southerly trend. The mine is equipped with a substantial steam hoist, but as yet has no mill. 20 men are employed.——The Bunker Hill Consolidated Mining Company, owners. C. R. Downs of Sutter Creek, superintendent.

Fremont Mine.—This property, 1½ miles north of Amador City, comprises the Fremont, Gover, and Loyal Lode, 4200 feet on the lode. The principal work on this property is on the Gover Mine, the main shaft of which is down 1500 feet on an incline, being 1050 feet vertical. There are ten levels, and in the lower levels of the mine there are developed large masses of low-grade quartz. In the early part of the present year, a new shaft was started on the Fremont claim. This is an inclined

Keystone Consolidated Mining Company of San Francisco, owners. W. A. Prichard of Amador City, superintendent.

Keystone Mill.—The mill consists of 40 stamps, and two Griffin mills. The latter were formerly used in crushing the fine material from the mine, but are at present not in use. The mill is run by water power, and the hoist by steam. The mill is under the direction of C. E. Bunker. The stamps when new weigh 725 pounds. Prior to March 10, 1890, they were dropped 90 times a minute. A Pelton wheel was put in the mill at this time to run the concentrators independently, and the stamps were speeded to about 100 drops a minute, the height of the drop being from 7 to 7½ inches, and the discharge 7½ inches high. Nos. 6 and 7

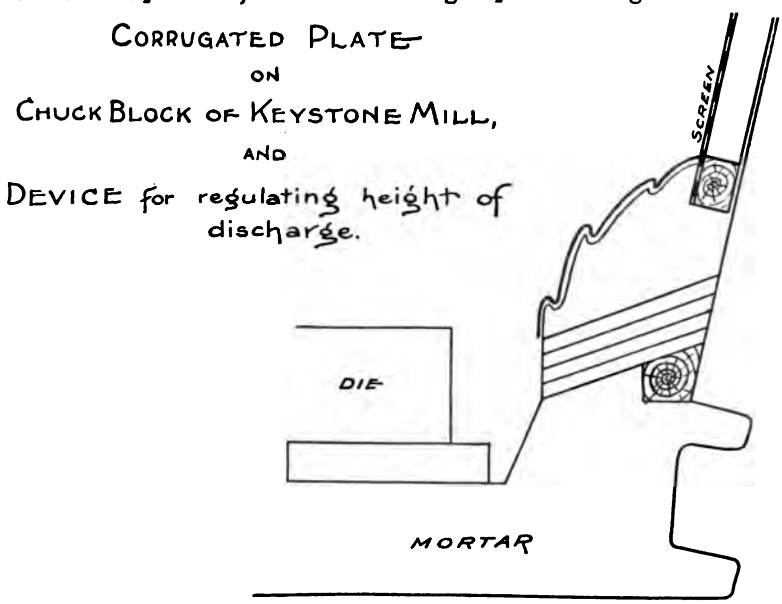


FIG. 27.

angle-slot steel screens are used. The chuck-blocks are arranged so as to drop half an inch at a time. A variety of shoes and dies have been tried here, including cast-iron, manganese, chrome, and hammered steel. The capacity of the mill per stamp is 2½ to 3 tons per day, varying somewhat with the character of the ore. This low capacity is probably attributable to the light-weight stamps. The inside plate is curved, and 6 inches in width. The apron plates are 52 inches wide and 4 feet long, having a grade of 1¼ inches in 12. Below this the plates are narrowed to 48 inches for a length of 10 feet, below which they are further narrowed to 30 inches and 24 inches long, with a trap at the bottom.

Since February 1, 1900, numerous changes have been made in this mill. On an experimental battery, the chuck-block has been changed

surface. This period is determined by holding a bottle of ammonia near a small vent in the cover. Upon the appearance of the chlorine gas through this vent, a dense cloud of chloride of ammonium at once forms. Water is introduced through a hole in the cover, falling on a burlap sack. It is a common practice to allow the water to stand from one to two hours, when it is turned into the precipitating tank. The water is permitted to run until the iron sulphate solution fails to show the presence of gold, samples being taken from the vat. If the assay of samples shows that high values remain in the pulp, it must be removed from the vats and "regassed." The leaching vats are provided with a double floor; these are made with slats 1½ inches in width placed 18 inches apart. Upon these and at right angles to the first are laid 1-inch boards 4 inches wide, covering the bottom; these are 2 inches apart. Upon this floor is placed a quantity of quartz gravel (clean creek gravel being preferred), usually laid in courses, to a depth of about 6 inches. Upon this filter are laid the shoveling boards, 4 inches wide and 1 inch in thickness, they being separated by a space of 1 inch. These spaces are filled in with fine gravel which will pass a No. 12 screen. A solution of iron sulphate is employed to precipitate the gold from the chloride solution. The precipitate is washed and smelted with borax.

Centennial Mine.—This property is 1½ miles northeast of Drytown. An inclined shaft has been sunk 565 feet, and sinking was in progress in April last. This shaft, started on the vein, passes into the foot-wall, and cross-cuts are run to the vein at the 150, 250, and 350 levels. On the first the vein was found from 8 to 8 feet wide; on the second, 18 feet; and on the third, about 2 feet. The shaft will be continued to a depth of 1000 feet. The formation is greenstone schist (after diorite). ——Centennial Mining Company, owners. L. A. Gross of Drytown, superintendent.

The formation from the neighborhood of Drytown to Plymouth is largely amphibolite schist and diorite, tufaceous slates, and Mariposa clay slates. Many veins of quartz occur, both large and small, and also zones of amphibolite schist with quartz. There are many prospect holes of various depths throughout the region, but with the exception of those here mentioned, no operating mines.

Plymouth Consolidated Mine.—This property is at Plymouth, and has been idle for many years, but within the past year the old dumps have been worked with profit in Huntington mills. These dumps were estimated to contain over 250,000 tons of rock. The reduction plant consists of four 5-foot Huntington mills with hydraulic sizers, Wilfley and Woodbury concentrators, and canvas plant. Power is furnished by water from the Hayward ditch under a head of 572 feet. The dumps

were moved at very low cost by cutting in at their base and running an open cut directly into the end of the pile of rock. When a face of sufficient size had been exposed, a movable chute was placed against the face, by means of which all the rock above the level of the chute was easily delivered to cars beneath the chute. The rock was trammed to the mill, hoisted in the car by means of a hydraulic elevator, dumped onto the grizzlies, from which it passed to the rockbreakers, falling into a bin. From the bin, the rock was delivered to automatic feeders, thence to the mills.

Diagonal slot screens from 12 to 20 mesh are in use. From the mill the pulp flows to the sizers, from which the coarse material goes to the concentrating tables and the slimes to the canvas plant. The principal source of value in the dumps is in the sulphurets, which average about 1¾ per cent. The free gold is caught with the concentrates, which are shipped to Selby's. The following statement is made by the management relative to the cost of working:

Thirty Days' Milling, 3750 Tons.

Cost of delivering rock to mill	$375 00
Milling, including canvas plant	510 00
Water	240 00
General expense	110 00
Total	$1,235 00
Total cost per ton	32

——The New Western Mining and Reduction Company, owners. T. C. Woodworth of Plymouth, superintendent.

Pocahontas Mine.—This property is 1½ miles east of Drytown, and includes the Pocahontas, Edson, and California, the owners holding a bond on the Maryland claim adjacent. A vertical shaft has been sunk on the Pocahontas to the depth of 620 feet, with six levels. The formation is practically a black tufaceous, pitted slate, to the west of which lie the Mariposa clay slates. Over 1000 feet of cross-cuts have been run, extending from the Mariposa slates on the west to massive diabase on the east. The property is provided with a good steam hoist, and a 10-stamp mill run by water power. There are 6 men employed.——The Pocahontas Improvement Company of Drytown, owners. Allen McWayne of Drytown, superintendent.

Pioneer Mine.—It is 1 mile south of Plymouth, and comprises a mile on the lode, which consists of two veins; the east or hanging-wall vein of massive quartz, and the west vein banded structure. The latter is usually the better vein. These veins occur in the black tufaceous slates. An inclined shaft has been sunk 500 feet on the foot-wall vein, and in the several levels three shoots of ore have been developed. In some respects these shoots of ore are similar to those of the Central Eureka at Sutter Creek. The lower workings of the mine, however, are in low-grade ore, and appear to have reached a zone of little or no pay rock,

which seems to be a peculiar characteristic of many of the most important mines of Amador County. Geologically, the outlook for the future of the Pioneer Mine may be considered as encouraging, as there is no reason to anticipate that it may not at greater depth repeat the experience of the Kennedy and Argonaut, Central Eureka, and other mines in this county.——Dr. Thomas Boyson, owner.

Philadelphia Mine.—It is 4 miles north of Plymouth, near the Bay State. Several years ago this mine was opened by means of a large cut and drift, when operations were suspended, and the mine remained idle until the spring of 1900, when a new double-compartment shaft was started 1000 feet south of the old open cut. This shaft had reached a depth of 80 feet early in June. Its hanging-wall is diabase; the foot-wall is black slate. The vein formation is 20 feet in width. There are kidneys of good rock on the foot-wall side. The shaft is equipped with a water-power hoist, capable of going 1000 feet.——J. J. Crawford, Claus Spreckels Building, San Francisco, owner. Leased to J. R. Roaf et al. of Toronto, Canada.

Ivanhoe Mine.—It is 1½ miles northeast of Plymouth. The mine occurs in a zone of amphibolite schist, and is developed by a vertical shaft 130 feet deep, and also by an inclined shaft 120 feet. It has a 20-stamp mill and a steam hoist. It has been described in former reports, and was closed down in the spring of 1900.——Under bond to the Ivanhoe Gold Mining Company of Salt Lake. E. Brent of Sutter Creek, superintendent.

Shenandoah Mine.—It is 1½ miles northeasterly from Plymouth. This interesting vein adjoins the Red Cloud, described in former reports, on the south. The formation is diorite, which, near the vein, is altered to amphibolite schist. The shaft, early in May, had reached a depth of 375 feet, partly on the vein, but the lower portion in the foot-wall. Drifts were run at the 200 and 375 levels, the latter from a crosscut. There are two veins in this fissure, one a massive vein of quartz, the other a banded or ribbon vein. On the south side of the shaft the banded vein lies on the hanging-wall side of the fissure, but on the north side it is found on the foot-wall side, being separated from the massive vein by a small gouge. The massive vein appears to be the older, it having been broken and crushed by the movement of the rocks. The banded portion of the vein, however, is quite regular, and shows no structural indication of disturbance. In addition to gold, there are found iron, lead, and copper sulphides. The shaft has been sunk between two shoots of ore, which have a southerly trend. The mine is equipped with a steam hoist, but has no mill. There are 12 men employed.——Shenandoah Mining Company of Sacramento, owners. S. K. Thornton of Plymouth, superintendent.

Red Cloud Mine.—It is 1½ miles northeast of Plymouth, adjoining the Shenandoah on the north. It has geological characteristics similar to those of the Shenandoah. It is idle. The shaft has been sunk to a depth of 365 feet, the upper portion of which was caved at the time of my visit. The surface croppings are exposed in cuts, and show two veins striking N. 13° W. and dipping 65 degrees to the east. The shaft appears to have been sunk at a point where a fault has displaced the vein, giving the appearance of two veins, whereas there is really but one.——The Red Cloud Mining Company of Stockton, owners.

Gowanus Mine.—It is 2 miles northeasterly from Plymouth. In this property there are several large lens-like masses of quartz striking through a much foliated amphibolite schist. These lenses have a width of from 1 to 8 feet, and occur across a zone of 150 feet or more in width. They appear to converge northward. The ore is granular, and of a dark blue color resembling some quartzite. It is said to mill $8 per ton. A three-compartment shaft (vertical) was being sunk during the spring of 1900, which was calculated to reach the vein at a depth of 200 feet. At this mine was found an unusual arrangement of a hoisting plant. The hoist, which is run by steam, is set opposite the end of the shaft instead of at the side. This was done with a view, it was explained, of leaving the ground for a permanent hoisting plant unobstructed, and of permitting the temporary plant to be operated until the new hoist could be placed in position. There are 8 men employed.——Gowanus Mining Company, owners. Mr. Rogers of Plymouth, superintendent.

Bay State Mine.—It is 4 miles north of Plymouth. There are several veins in this property. That known as the Bay State vein was formerly worked by the Bay State Company to a depth of 830 feet; it was stoped from the 400 to the 600 level. At the 750 level a cross-cut was run east to the vein and two shoots of ore developed, one dipping north, the other south. The north shoot is a banded vein, the south more massive and mixed with slaty material. The sulphides found in the south shoot were high-grade in gold. At 460 feet west, on the 750-foot level, a west vein was discovered in the cross-cut, which is called the Kretcher vein. This vein was observed at a point 346 feet west of the shaft on the 300-foot level. The Kretcher vein has been developed for a distance of about 300 feet, and consists of banded quartz of good grade. At the time of my visit some improvements were being made in the shaft, but the mine was not in full blast. The shaft will be sunk an additional 300 feet. The mine is equipped with a good hoist, and has a 10-stamp mill and an 8-drill air-compressor, all run by water. The pumping is done by air. The mill has a capacity of 40 to 50 tons daily. A 24-mesh punched tin screen is used. The pulp passes directly from the battery to the vanners, of which there are four. The tailings

are stated to contain but 21 cents per ton, chiefly in free gold. The sulphides are shipped to the Drytown chlorination works. There are 12 men employed.——The Globe Mining and Milling Company of Stockton, owners. J. L. Bryson of Plymouth, superintendent.

Rhetta Mine.—This mine is about 4 miles north of Plymouth, adjoining the Bay State on the south. It is developed by means of a cross-cut tunnel about 600 feet in length. There are two veins on the property. One occurs at the contact of a diabase foot and a black slate hanging; the other branches out from this contact vein, striking northward in the hanging-wall slates. Both of these veins have been explored with satisfactory results, the ore being hauled to the Bay State mill at a cost of 30 cents per ton. A large amount of water is encountered, but this causes little trouble, as it passes out through an adit tunnel. From the Rhetta vein southward in the direction of Plymouth, a line of springs marks the occurrence of fissures at or near the contact of the slates with the greenstone, and although this section affords a good field for prospecting, very little has been done toward exploring. There are 8 men employed.——Rhetta Gold Mining Company of Stockton, owners. J. L. Bryson of Plymouth, superintendent.

Talc Mines.—About 6 miles west of Sutter Creek is an interesting occurrence of gold in foliated talc schist, which appears to be a structural alteration of serpentine. On the Tonzi and Waechter ranches there are several zones of this talcose rock, in which the gold occurs in extremely thin plates in the foils of the rocks, much of which is thin as the finest gold leaf; while presenting the appearance of richness, gold of this character is very deceptive. On the Tonzi ranch, Mr. Tonzi has erected an ingenious device for crushing this ore, and claims to have taken out considerable gold at various times from the best selected gold-bearing material found on his place. That this gold-bearing talc can be profitably worked, is extremely doubtful; it is possible that if a zone of sufficient size, carrying $5 or more per ton in gold of the character described, could be found, it might be profitably treated by some modifications of the cyanide process.

Azula Mine.—This is 3½ miles northeast of Ione. It is a pocket mine in diabase, and has been worked with considerable success by its owners. Mining here is carried on in rather primitive fashion, but evidently with satisfactory results. The vein is from 16 to 18 inches in width, the small stringers going into the main fissure from the hanging-wall. Three men employed.——Adams, Burris & Smith of Ione, owners.

Nugget Mine.—This property is near the Azula, and is similar to it. It has a small steam hoist, and a 5-stamp mill has been constructed since my visit to the property; it was idle at that time.——Dr. Adams et al. of Ione, owners.

Queen Mine.—This is in the same group with the Azula and Nugget, and is geologically similar to the others. It has a small steam hoist.——Newman, Bagley & Frates of Ione, owners.

Ranlett Copper Mine.—It is located 3 miles northeast of Ione. The ore-bodies occur in the greenstone schists in which are found many of the copper mines in this State. The ore is that most common to copper mines in the West, and is amenable to treatment by various smelting methods. The development of the mine, while not extensive as compared with the great gold mines of the State, is sufficiently so to show that it is a mine of considerable possibilities. An examination of the mine and maps, together with the statement made by Colonel Ranlett, indicates about 30,000 tons of ore in sight, including that now on the dumps. The ore may be divided into two classes: a vein of solid, massive, yellow sulphide copper ore, distinctly separated from the adjoining rock, and in the foot-wall a zone of variable width, from 4 or 5 feet to 15 feet or more, in which occurs a large amount of iron sulphide, with a small percentage of copper sulphide. In this zone there are segregated bands of ore above the average of the zone in value, and which by rough sorting may afford a valuable product, though, of course, not so high a grade as that found in the massive vein. This ore contains considerable silica, and may become valuable as a flux in treating the more massive ore. The levels already opened are practically without cross-cuts; at least, such as have been made are not in ore, and others should be made in the foot-wall for the purpose of determining more fully the extent and value of the low-grade zone. Manila ropes are in use in this mine, steel ropes not having given satisfaction in former years; but I believe that as so many years have elapsed since steel ropes were employed here, it would be found that the modern steel rope would prove superior to the large, cumbersome Manila ropes now in use, even in the present old crooked shaft. I am positive that such would be the case in the proposed new shaft, which would be sunk at a uniform angle. A water-jacket smelter of 100 tons capacity daily was built at this mine during May and June, 1900. Not yet blown in, June 10, 1900.——H. G. Ranlett of Ranlett, superintendent.

EL DORADO COUNTY.

This county, which in past years has produced a very large amount of gold, is at present passing through a temporary period of inactivity, due partly to scarcity of water and to other causes not wholly apparent. There have been in the past in this county, and there are still, mines of undoubted merit, a statement abundantly proven by its history, and that the mines of El Dorado are exhausted cannot be entertained. Some large and extensively equipped enterprises have come into prominence and have been shut down since our last report, but the fact that there are those who have been led into unprofitable investment by reason of the exercise of too little caution should not, and probably will not, deter others from engaging in the legitimate pursuit of mining enterprises in this county on more conservative lines. No mining county in California, and no mining region on earth, is wholly free from these monuments of men's folly. It is a fact that in no county in California has mining been carried on at less expense than in some of the mines of El Dorado, and it still offers abundant legitimate and promising opportunities to those with both the capital and experience to handle large low-grade mines.

In passing northward from Amador County into El Dorado, the Central Gold Belt, or so-called Mother Lode, appears to split up. The geological conditions for a distance of five miles in El Dorado County are not wholly dissimilar from those of Amador, consisting essentially of massive outcrops of white quartz at or near the contact of slaty rocks and massive greenstones. These heavy outcrops of quartz are rarely gold-bearing in amount sufficient to constitute payable rock, and they are frequently accompanied, as elsewhere along the Gold Belt, by veins having a slaty structure, in which the gold contents are sufficiently high, in some cases at least, to afford profit.

When the neighborhood of the German Mine is reached, 5 miles north of the Cosumnes River, we find a new and strange intrusive rock—one with which we are not familiar in the region farther southward. A study of this region shows that in proceeding northward some of these rocks are of granitic type, ranging through grano-diorite and diorite to quartz-porphyry, and other porphyritic rocks. As we go farther northward, the rocks of this character increase in area, until in the neighborhood of Placerville they largely dominate all other kinds, although the rocks with which we are familiar farther southward (the greenstones) may still be found. On a prominent hill just north of the

hurch Mine are large masses of rock of granitic type, of which a careil investigation was made. The granitic outcrop was found to be half mile in width, striking with the general trend of the country in a ortheasterly direction. On the eastward, large masses of diabase and nphibolite schist are found. A number of rock specimens were ollected from various portions of this mass, and slides were prepared ad studied by Mr. H. W. Fairbanks of Berkeley, whose report accomanies this bulletin. This investigation shows that specimens selected any particular portion of the mass, and assumed to represent the ntire intrusion, would be very misleading, for, in the several slides ade from specimens taken from different portions of the hill, we find ocks of a decided acid character, and also those of basic kind, with any intermediate phases. (Nos. 30, 31, 32, and 33.) The specimens los. 26, 27, 28, and 29 are of similar rocks from Logtown and vicinity. n some, hornblende is abundant, and in others augite is a prominent onstitutent; in still others, both of these bi-silicates appear. Some of he rocks have abundant free quartz, in others none is visible to the naided eye. They also vary greatly in the kind and amount of feldpars they contain. Southward from this hill, in the direction of the ierman, Pocahontas, and Starlight mines, and the country about Logown, are numerous intrusive dikes, large and small, of rocks of the bove described characteristics, and in some of the masses rich goldearing deposits or veins have been discovered and worked, notably in he Pocahontas at Logtown. In the neighborhood of Placerville is ound, near Diamond Springs, and extending northward beyond Placerille, another section of the great dolomitic vein which is characteristic of the Central Gold Belt in Calaveras, Tuolumne, and Mariposa Counties. Here is seen the same broad zone of dolomite, or ankerite, in which occurs an abundance of the beautiful, scaly, micaceous mineral, mariposite. Although the Pacific Mine in Placerville has been idle and inaccessible for many years, the old dumps clearly show the character of the geological formation. In this mine the ankerite has been compressed, sheared, and deformed, the original material being altered into a perfect talc schist. When this occurs, mariposite usually disappears, or, if present, cannot longer be detected by its characteristic green color. Serpentine also accompanies this belt, which is not an uncommon accompaniment southward. In the Pacific Mine, the serpentine is frequently found altered to a dark-green talc schist, which may be readily distinguished from the white schist resulting from the alteration of the dolomite.

The black slates found associated with the mineral veins between the Cosumnes River and Placerville are chiefly the result of the alteration of diabase tuffs, which has been described at length in the introductory paragraphs of this bulletin. Mariposa clay slates are also

found. Owing to the very unsettled state of the weather and the difficulties and delays attending transportation in March, the investigation of this section was not carried north of Placerville until the summer season.

German Mine.—It is 5 miles south of El Dorado. This was the first accessible developed mine going northward last spring in El Dorado County from Amador in which we find a material change in geological conditions. The general formation of the country consists, as it does farther southward, of massive diabase tuffs, amphibolite schists, and the clay slates of the Mariposa beds. Here we also find the black slates resulting from the alteration of the diabase tuffs which have been previously described as being intimately associated with the ore deposits of the principal mines of Amador County. The gold-bearing veins of the German Mine are found inclosed in these tufaceous slates, and the vein structure does not differ materially from the veins of Amador. The clay slates of the Mariposa beds lie both to the eastward and to the westward of the main fissure, but not in contact with it. The most striking geological feature of this mine is the intrusion of acidic dikes, which present various phases ranging from quartz-porphyry to granite. There were evidently several intrusions of different ages. These intruded dikes have been sheared and have suffered deformation in a manner similar to that characteristic of the altered diabase. These dikes in width vary from a few feet to more than a hundred feet, and in more than one place the larger dikes were found to contain zones of crushed material into which free silica has infiltrated, together with iron sulphides and gold, but to what extent the zones are gold-bearing has not as yet been determined. One intrusive mass which attracted my particular attention was found above the 100-foot level. It has been intruded from the southward into the slates, and, as viewed in the mine excavations, it looks like the stern of a great ship as it appears when lying in drydock. A banded, slaty vein follows around this peculiarly curved intrusion, having the granite on one wall and the slaty tuffs on the other. The mine is equipped with a water-power hoist and a mill of 10 stamps. The stamps weigh 950 pounds, and drop 6 inches, 100 times a minute. The discharge is 7 inches high, and a 30-mesh brass wire screen is used. This mill has a capacity of 3¼ tons per stamp. Below the battery plates, a shaking-riffle table has been introduced for the purpose of saving any amalgam escaping the plates. It is said to give satisfaction. A Wilfley concentrator is employed to concentrate the sulphurets, which constitute about 1½ per cent of the ore. These are shipped to Selby's reduction works.——German Mining and Milling Company of San Francisco, owners. C. O. Richards of El Dorado, superintendent.

Buena Vista Mine.—It is 1 mile east of the German Mine, and 5 miles southerly from El Dorado. The veins are found in Calaveras formation—mica schist at this place. A small vein running parallel with the strike and dip of the schists has been followed for some distance in search of pockets, with satisfactory results. A former operator who prospected this mine, in some way was misled as to the value contained in a schistose zone impregnated with iron sulphides, and expended nearly $50,000 on the property, doing considerable development work, erecting numerous buildings, and a mill. The rock proved almost valueless, and the mine was closed. The present owners, however, are doing well.——C. O. Richards of El Dorado, owner. Grant Hill of El Dorado, lessee.

Last Chance Mine.—This vein is 1 mile east of Nashville, and is from 1 to 8 feet wide, occurring in the slates of the Calaveras formation. The vein has a beautiful ribbon structure, and has been developed by a tunnel driven on the vein. A light-colored dike accompanies the vein. The property is equipped with a 2-stamp mill run by gasoline engine. The property is idle.——A. C. Smith of Portland, Oregon, owner. H. E. Smith, in charge.

The Center Mine.—Owned by a New York company, and is near the Last Chance. Idle.

The Nashville Mine.—This mine is south of the Last Chance, and is equipped with a steam hoist. Idle.——E. J. Baldwin of San Francisco, owner.

Madelina Mine.—It is 5 miles south of Diamond Springs. This vein or zone is from 40 to 60 feet in width, in the Calaveras formation. There is a gouge and dike rock on the foot-wall. The ore is pyrrhotite, chalcopyrite, and pyrite with gold. The ore is extremely hard, and a great portion of it contains a very large percentage of the sulphides mentioned. It offers a problem in economic metallurgy. The vein is developed by means of a cross-cut tunnel 90 feet to the vein, and a drift along the foot-wall 100 feet, connected by a raise 105 feet to the surface.——Williams & Bier of El Dorado, owners.

Noonday Mine (Copper).—This property, near the Madelina, when visited, was simply a prospect having a 15-foot shaft and several open cuts on a 7-foot vein consisting chiefly of iron and copper sulphides, the latter ranging from a trace to 25 per cent. It may be considered a promising prospect.——Bonded to Dr. Procter of Placerville.

Montezuma Mine.—At Nashville. This property after an idleness was about to start up in the spring of 1900.——J. C. Heald of Nashville, owner.

Union Mine.—It is 3½ miles southeast of El Dorado. It was formerly known as the Springfield, and was operated by Alvinza Hayward to a depth of 1700 feet. Within the past two years the mine has been operated by a company, and a 30-stamp mill built. On another group of mines in the vicinity a new shaft was being sunk in March, 1900, and though less than 100 feet in depth, a 20-stamp mill was being erected. These properties are under the management of A. Harpending, and were the only ones visited during the season where inspection was denied and information refused. It was currently reported that a large amount of gold was being taken out, but I was unable to confirm this report. There are 45 men employed at these two mines.——A. Harpending of El Dorado, superintendent.

Church Mine.—It is located 8 miles south of Placerville, and 2½ miles from El Dorado. Three veins occur in the slates; they are well defined, and have hard walls and a gouge on both foot and hanging walls. The two veins mostly developed are of variable thickness, laminated, and carrying considerable sulphurets. There is also an east vein, known as the Union, which is being worked near the south end of the property on the adjoining Union Mine. Surface prospects on this lead in various places give a result of from $2.35 to $26 per ton. The vein worked by the former company was termed the Kidney vein, and has been worked to a depth of 1350 feet, taking out the best of the ore and leaving the low-grade ores. This vein averages 5½ feet in width, and the rock taken from it milled from $28 to $30 per ton. The prospective value of the mine is based on the value of the west vein, first discovered on the 350-foot level while sinking the shaft on the Kidney vein. There were milled from this ledge 3000 tons of ore taken from the various levels from the 350-foot to the 1200-foot level, which returned $2.50 per ton free gold and about 2 per cent sulphurets, worth $67 per ton; the tailings, owing to a lack of facilities in the mill, averaged $1.27. This vein in many places is from 14 to 20 feet wide, averaging 8 to 10 feet. The main shaft is 1200 feet deep vertically, with a 40-foot sump, and has three compartments. Stations are cut at each level. The mine is equipped with a water-power hoist, and is provided with 3000 feet of steel cable. The compressor has a capacity of five 3-inch drills. The pumping plant, consisting of plunger and jack-head pumps, has a capacity of 150,000 gallons per day, which is about double the amount of water the mine makes. The mill has ten 950-pound stamps, four Frue concentrators, clean-up barrel, pans, etc. The machinery is run by water power taken from a reservoir owned by the company; at the mill there is a head of 485 feet.——Church Mine Development Company of San Francisco, owners. John Ross, Jr., of Sutter Creek, superintendent.

Griffith Mine.—It is half a mile southeast of Diamond Springs and half a mile from the Larkin Mine. Since the last report, this mine, at

that time a mere prospect, has been elaborately equipped with hoist, mill, etc., and an expensive electric power plant, by a Scotch syndicate. After a few months of active operation, the mine was closed down and nothing has since been done there. It is locally reported that it did not pay.——Griffith Mining Company of Glasgow, Scotland, owners. G. P. Gow of Stent, agent.

Larkin Mine.—One-half mile east of Diamond Springs. The great dolomitic vein passes through this property, in addition to which there are several other, though less prominent, veins. It is upon one of the latter, which occurs in the hanging-wall slates of the dolomitic vein, that operations are at present being conducted. This vein is accompanied by a small dike of diabase, and possesses the usual characteristics of veins in slate. The dolomitic vein is 80 feet in width, and is altered more or less to talc schist. The dolomite here appears to contain iron carbonate, and is properly ankerite rather than dolomite. The ankerite vein is also cut by dikes, a feature not observed elsewhere, and the foot-wall portion, for a width of several feet, is impregnated with quartz and pyrite, but no exploration had at the time of my visit been conducted on this mineral zone. There are several small veins in the amphibolite schist of the foot-wall, but these, too, remain unexplored. This mine has a 10-stamp mill, the stamps weighing 1000 pounds, dropping 110 times a minute. A No. 1 punched tin screen is employed. The discharge is 9 inches high, and the capacity of the mill under these conditions is said to be a little in excess of 3 tons per stamp per day of twenty-four hours. The ore contains 1½ per cent of pyrites. These have been shipped to Selby's, but experiments with the cyanide process have demonstrated that the gold can be extracted from the sulphides by this means without preliminary roasting or other treatment. Of the gold obtained by amalgamation, about 55 per cent is recovered in the battery.

An ingenious experiment has been tried by the superintendent with a view to prevent scouring of the inside copper plates. This consists of a cast-iron plate having the shape of a segment of a cylinder to fit the copper plate. It is ½ inch in thickness, with slots ½ inch in width and 20 inches in length. Within these slots the amalgam accumulates and remains. Concentration is accomplished on a single Wilfley table. A vertical shaft has been sunk 600 feet, and a cage is in use. There are 35 men employed.——Larkin Mining Company of San Francisco, owners. G. B. Jacobs of Diamond Springs, superintendent.

Selby Mine.—It is 1 mile east of Diamond Springs, near the Larkin Mine. Idle.

Marguerite Mine.—It is 1 mile east of Diamond Springs, near the Larkin Mine. Idle.

Tin Cup and Ribbon Rock Mines.—These mines are 2 miles south of Placerville, and are being operated under bond by A. Hayward of San Francisco. When visited, the main shaft was down 100 feet in "ribbon quartz" 5 feet wide showing gold, and for amount of work done it was considered the best prospect in that section of the country. There are 10 men employed. Since writing the above the shaft has been sunk to 200 feet and a heavier hoist installed.——E. A. Davis of Placerville, superintendent.

Gentle Annie Mine.—It is 1 mile north of Placerville. This comprises a property 1000 feet by 1700 feet, covering five parallel veins, of which the principal one appears to be the dolomitic vein, which has been previously described as characteristic of some portions of the Gold Belt. The mine, while extensively developed and equipped with a 10-stamp mill, has been idle since October, 1899, awaiting adjustment of the affairs of the Melton estate. There are two large air-compressors and a hoist, which may be operated by either water, air, or steam.——B. G. Parlow of Placerville, superintendent.

Revera Mine.—On Texas Hill, 3 miles east of Placerville. This is a drift mine, to which a bedrock tunnel was being driven 900 feet to the channel, which, on March 15th, had penetrated a distance of 600 feet. The property is equipped with a mill having a Dodge pulverizer with a capacity of 125 tons daily, running 15 revolutions a minute; there is also in the mill a Krough shaking-riffle. The mill is run by water power under 169 feet head. A self-discharging tank was a feature of the works, so arranged as to sluice out accumulated tailings. Since writing the above the tunnel has reached the channel, and is reported to be in pay gravel. Parker Bros. of Placerville, owners. C. L. Parker, superintendent.

Ellen Taylor Drift Mine.—It is 4 miles west of Indian Diggings. Sluicing and piping were in progress in the spring of 1900. There were 11 men employed.——A. B. Spreckels et al. of San Francisco, owners. F. J. R. Dawson, superintendent.

Umatilla Drift Mine.—This is in El Dorado County, 12 miles northeast of Plymouth, Amador County. The mine has been worked steadily for the past two years. The gravel channel varies greatly in width, and ranges from a few inches to 4 feet in thickness. The gravel is crushed in a Krough hexagonal mill, similar to the Dodge pulverizer, and has a capacity of 250 tons per day. Below this machine is a shaking-riffle, in which the gold is caught. The machinery is operated by water power.——Umatilla Mining Company of San Francisco, owners. C. O. Richards of Ono, superintendent.

Placerville Slate Quarry.—It is 1½ miles north of Placerville. Here a quarry has been opened upon a reef of slate 150 feet or more in width,

standing nearly vertical. A large portion of this slate appears to be of merchantable quality. The slate, after having been prepared for market, is hoisted to the top of the hill on an inclined tramway, the car being run from the quarry track directly upon the car or giraffe. The tramway is double. On the opposite track from the giraffe is a car carrying a steel cylinder with a capacity of several hundred gallons. This is filled with water at the top of the incline, and when its weight overbalances the weight of the giraffe, carload of slate, and cable, it moves downward, hauling the car up the incline, its speed being controlled by a brake at the head of the tramway. The water cylinder discharges automatically at the foot of the incline, when the giraffe and car return to their places at the loading station. This company has taken contracts to furnish slate for the buildings of the Mountain Copper Company at Keswick, Cal.; for the Government, and elsewhere. There are 10 men employed.——Placerville Slate Company, owners. G. W. Cummings of Placerville, manager.

Pocahontas Mine.—It is 3 miles south of El Dorado. The vein, which lies at a low angle with a curving strike, occurs in a feldspathic porphyry (No. 26), through which is scattered many crystals of bronze-colored mica. This peculiar rock when examined in sections under the microscope is seen to be a diorite-porphyrite. The property was at one time well equipped with machinery, having hoisting works and a 10-stamp mill, but these have been removed and the mine has been idle for some time, although at one time producing handsomely.——Q. A. Chase of San Francisco, owner.

Minnehaha Mine.—This is 3 miles south of El Dorado P. O., near Logtown. The vein occurs in quartz-porphyry much silicified, and containing a small amount of iron sulphide with coarse free gold. The vein strikes N. W. and dips N. E. about 10 degrees below the horizon. There is no parting between the vein and the country rock, the ore passing over gradually to the country rock. In one place along the surface in the hanging-wall was found a zone of porphyry with many quartz seams carrying gold. These were dipping toward the flat vein, but had not been reached in the mine workings. The rock is crushed in a 4-stamp mill. No concentrators were in use; 8 men employed.——Minnehaha Gold Mining Company of San Francisco, owner. Froehlich & Perham of El Dorado, lessees.

Starlight Mine.—Three miles south of El Dorado. The ore in this mine occurs in large lenses in a much altered, silicified diabase. There are several shafts on the mine provided with steam hoists, and there is a 10-stamp steam mill, which is supplied with ore from the several shafts by means of a rope tramway, having a capacity of 35 tons a day. The ten stamps weigh 1000 pounds each, and drop 6 inches 100 times a

minute. The discharge is 7½ inches high. A No. 8 vertical-slot screen is employed. Concentration is effected by the use of two Union machines and a canvas plant. The ore contains 2 per cent of sulphurets—pyrite, galena, and arsenical sulphide. The value, however, is chiefly in free gold.——Starlight Gold Mining Company of San Francisco, owners. J. A. Vance of El Dorado, superintendent.

Oro Fino Mine.—This property, which has been repeatedly described in former reports, was found working as usual. It is situated 5 miles south of Diamond Springs. The vein, which is 40 feet wide, consists of a dike-like mass of diabase breccia which has become silicified and impregnated with finely disseminated auriferous pyrite. Many small seams of calcite traverse the rock in every direction. Both hanging and foot-wall country are diabase, but little altered even in close proximity to the vein. The vein material is extremely hard, and all ground is broken by machine drills, No. 1 Judson powder being used. A vertical shaft has been sunk to a depth of 200 feet, where it turns at an angle of 40 degrees and continues to a depth of 540 feet on the vein. The hoist is operated by compressed air. The mine has a mill of 30 stamps, which weigh, when newly shod, 1250 pounds. These drop 7 inches 105 times a minute. A 40-mesh punched tin screen is used, the capacity of the mill being 85 tons daily. No amalgamation is attempted inside the batteries. About one third of the values are in free gold, which is collected on the outside plates. The sulphides are concentrated on belt machines, and are treated in a chlorination plant owned by the company. Its daily capacity is 4 tons. A rotary conical breaker of the Gates type, being cast extremely heavy, has been found satisfactory in crushing this unusually hard rock. This mine has recently been shut down.——Hayward & Lane of San Francisco, owners. E. T. Kane of Canyon P. O., superintendent.

Vandalia Mine.—This interesting mine is situated about half a mile northerly from the Oro Fino. It has come into renewed prominence since the publication of the last report. In many respects it is entirely unlike others of the Gold Belt, though mines of somewhat similar character are known in Arizona, Nevada, and other portions of the Great Basin country. A description of the old Vandalia Mine will be found in the VIIIth report of the State Mineralogist. When being worked at that time, the ore was considered free milling, but still so large a percentage of the values was lost in tailings that the character of the mine was essentially the same then as now, though richer. The large ore-shoots developed by the present owners are not amenable to amalgamation, but the cyanide process, which has been applied in a rather rudimentary manner, has been found to operate satisfactorily.

When the present owners first visited the property, they tested the old tailings dumps which resulted from the operations of former owners,

and these were found to contain upward of $15 per ton in gold. A series of cyanide experiments soon demonstrated the adaptability of this ore to that process. The tailings dumps were first worked, and paid handsomely. Then the ore-bodies were attacked, and work has continued uninterruptedly since.

The ore deposits are found in a highly silicious felsite, having a semi-schistose structure, and in many respects are not unlike the quartz schists found in the Calaveras formation, though these latter are generally metamorphosed sandstones, and not of intrusive origin. The ore-shoots average over 80 feet in width and 300 feet in length, and cut both the strike and dip of the inclosing formation. The normal ore is essentially the quartz schist above described, heavily impregnated with iron sulphide, the oxidation of which has produced a mineralized zone extending from the surface to a depth of 100 feet or more, forming a reddish-brown iron cap or gossan. These ore-shoots are reached through adit tunnels, the lowest of which will, when extended, cut the ore-bodies 300 feet below their apex, and tunnels may be run at still lower points. The ore for most part, though heavily mineralized and oxidized near the surface, does not prospect at all in free gold, but always assays.

The mill found in operation at this mine was of home construction, made by the owners themselves, and is a rude, though ingenious affair, but not well suited to the class of work it is required to perform. It consists essentially of a revolving hollow cylinder resting upon four wheels or carriers, and provided with iron bars arranged transversely to its length, having about ½ inch space between them, similar to the Dodge pulverizer. In the interior of this cylinder are three so-called cams, which are really elevated ribs extending lengthwise of the cylinder and distributed at equal distances. The crushing device consists of three cylinders of iron, each 10 inches in length and 8 inches in diameter. These are connected at their ends by links, iron rods extending outwardly from each end of the connected cylinders to posts situated outside the machine. As the cylinder revolves, the cams, each in turn, lift the linked crushers until, clearing themselves, they fall backward a few inches, crushing the soft ore; this being repeated as long as the machine is in operation. The rock is fed through the open end of the cylinder, passing out between the bars, when crushed fine enough to pass the half-inch space between them. The machine is driven by a belt, power being furnished by a gasoline engine. As a result of this very coarse crushing, extraction of gold rarely exceeds 60 per cent.

The cyanide plant is situated about 200 feet from the mill, at the foot of an inclined tramway. The plant consists of two clear-water tanks, two stock-solution tanks, six percolation vats of 10 tons capacity each, two gold-solution tanks, and two sump tanks, together with the necessary precipitation boxes. The ore from the mill is delivered to the

cyanide plant by cars running on a double tram, the cars working in balance. Between the line of percolation tanks is a track running the full length of the plant, with a turntable at the center. The ore is dumped directly into the tanks, and distributed by shoveling at a cost of 25 cents per ton, including the cost of tramming. The cyanide solution is worked at about 0.25 per cent, with a consumption of 15 per cent cyanide. The ore is charged as described, and the solution turned in on top of the charge upon burlaps. It is allowed to stand three hours, when a valve is opened, and a pump connected with the weak solution in the sump tanks is started. This solution is pumped on at a rate equaling the progress of leaching, until the amount of solution charged is equal to the weight of the ore. The percolation process is usually completed in forty-eight hours. In the bottom of the precipitating-box an ordinary punched tin mill screen is placed, which keeps perfectly clean and shows no sign of corrosion. The cost of treatment is stated by the owners to be 50 cents per ton.——Seymour & Staver, owners and managers, Shingle Springs P. O. It is stated that this mine has recently passed into other hands, and is to be extensively equipped and operated.

Fortuna Mine.—It is 5½ miles south of Shingle Springs, near the Oro Fino Mine. At the time of my visit last spring, the mine and 5-stamp mill were idle, but the owners were building a ditch in anticipation of resuming operations.——Hale & Boughman of Canyon P. O., owners.

Monitor Mine.—It is 3 miles south of Canyon P. O. The vein occurs at contact of slate and greenstone. It has a shaft 60 feet deep, with a 50-foot drift at the bottom. The vein is 7 feet wide, and the rock is said to mill $6 per ton. The mine is provided with a steam hoist.——C. E. Schenks of Canyon P. O., owner.

Spanish Dry Diggings.—At this place, ½ mile northwest of Greenwood, a few men are making a living working the rich seams. No organized operations are in progress.

Altman Mine.—Near Greenwood. The property comprises 3000 feet on the lode. The principal development consists of a tunnel 500 feet long, which gives 250 feet backs. The mineralized zone is about 100 feet wide, and is stated to mill $3 per ton. A strip along the foot-wall, however, runs much higher. A 10-stamp mill formerly on the property burned. Two men are at work——John Smith of Greenwood, owner.

Gopher-Boulder Mine.—It is 1 mile north of Kelsey. The property was well equipped with electric power, but the generator house on Rock Creek burned. This is to be replaced. The mill contains 20 stamps and two 5-foot Huntington mills; these latter are stated to be equal to the 20 stamps in capacity. The vein is from 30 to 100 feet wide, but low-grade. A shaft has been sunk on the vein 250 feet, and a large open cut has been made in a zone of quartz and greenstone schist. Mining can

be carried on here very cheaply, as the company owns its power. At the Dalmatia, a mile distant, mining and milling were formerly carried on at a cost below 50 cents per ton. The Gopher-Boulder is idle, but it was stated that work would, in all probability, soon be resumed.——W. A. Bell of San Francisco, owner. W. H. Husband of Kelsey, manager.

Hayward Hydraulic Mine.—At Indian Diggings, on an ancient channel. There is about 150 feet of gravel, overlaid by over 100 feet of volcanic ash. The mine was extensively worked during the spring and summer seasons by hydraulic methods. About 1000 inches of water is employed in washing.——Plymouth Consolidated Mining Company, owners.

Eureka (Strale) Slate Quarry.—This property, situated near the village of Kelsey, was in operation during the summer, employing 20 men. Steam-operated power drills are in use. A superior quality of slate is produced at this quarry.——Eureka Slate Company, owner. W. A. Winsboro of Kelsey, superintendent.

Zantgraf Mine.—It is 7½ miles east of Newcastle, Placer County, and has been in operation for fifteen years. The principal shaft is sunk at an angle of 45 degrees in grano-diorite. It is 1125 feet deep. There are 10 levels open in the mine. Power drills are employed. Two shoots of good ore are on the main fissure, with 300 feet of low-grade rock intervening. On the 300-foot level a cross-cut, run 150 feet west, encountered a parallel vein, in which a shoot of pay rock has been developed. The sulphides, constituting ½ of 1 per cent, are high-grade, and with increasing depth it is stated that the percentage of sulphurets increases without any noticeable decrease in free gold. The north shoot on the main vein has been explored for a distance of 300 feet, and the face is still in good ore. The same shoot is being opened on the 300-foot level, where it is 600 feet long, and is also being developed on the 700 and 800 levels. On the 1100-foot level the shaft is in low-grade rock, but the north shoot is expected at the 1200, as it is pitching south. It is 150 feet from the shaft to the south shoot. The property is equipped with 25-stamp mill, and has a duplicate steam plant for both hoist and mill, though depending, under ordinary conditions, upon electric power. The company owns its power plant, which is located on the American River half a mile distant from the mine. The machinery was being renewed the past summer at the time of my visit. The stamps in the mill weigh 1035 pounds, when new. A punched tin screen is in use; the capacity is about 5 tons per stamp, with a discharge 5 to 6 inches high. This large capacity is due, of course, to the unusually coarse screen.——Montauk Gold Mining Company of New York, owners. Edward Goodwin of Newcastle, superintendent.

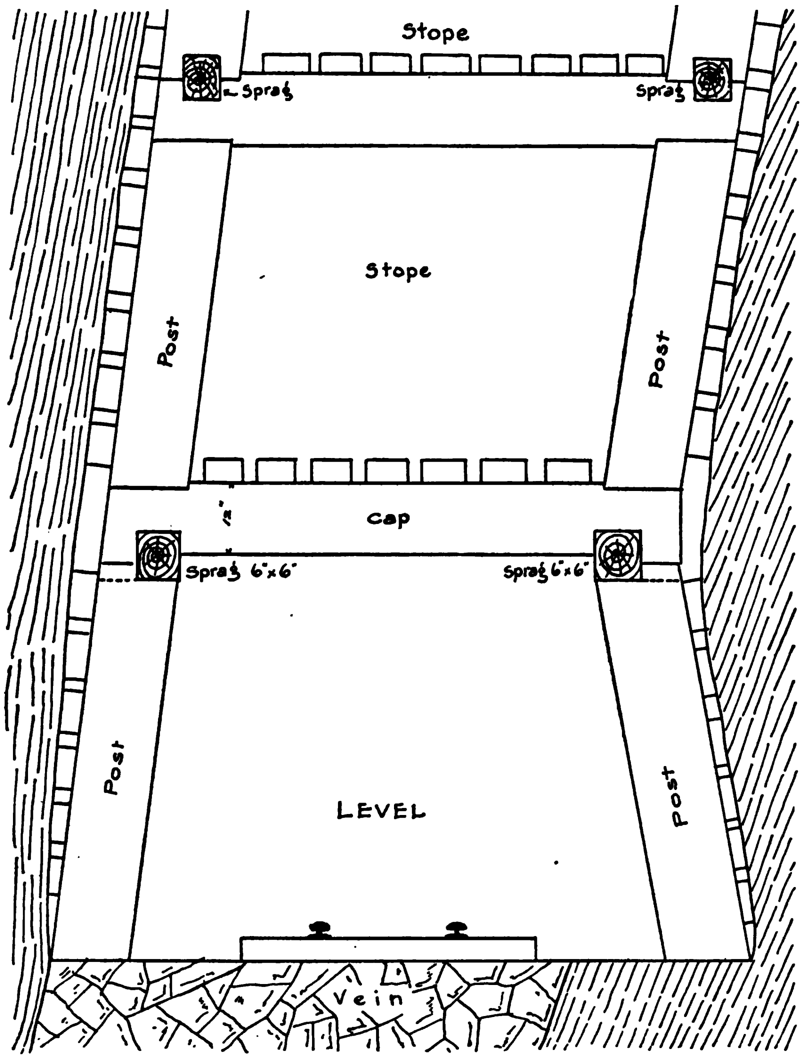
Jack Hanley Mine.—It is 2½ miles south of Greenwood. Prospecting is in progress. A rocking mill is in use. Four men are employed.——C. A. La Graves of Greenwood, superintendent.

CALAVERAS COUNTY.

In this county the mining industry is unusually prosperous, more so than in many years past. There are at work, and paying, no less than a dozen large mines, including three hydraulic mines, besides a great many small concerns, and a good deal of active prospecting is now in progress. Since the last report, a number of new enterprises have started up which are now idle, having proven unsatisfactory to the investors, but there are others which have, in a great measure, redeemed these more unfortunate ventures. Notable among the latter class is the Sheep Ranch Mine, which, after an idleness of nearly six years, has been reopened, and is again an active and, it is said, a profitable producer. The copper mines at Campo Seco are also being operated successfully, and in the Salt Spring Valley at Hodson the Royal Consolidated Mines are being worked on a much larger scale than heretofore. On the whole, Calaveras County may be said to be in a very prosperous condition. The development and exploitation of the new ore-bodies found in the Utica-Stickle and Gold Cliff properties at Angels will give a new lease of life to these important producers, and the operations of the Melones Consolidated Mining Company at Carson Hill will be among the most extensive in the State when carried to completion.

Gwin Mine.—It is 6 miles south of Jackson, Amador County. In its earlier history this mine was worked to a depth of 1540 feet through inclined shafts. Operations were suspended in the fall of 1882, and the property remained idle until 1894, when the present operators reopened the mine. A vertical shaft was started in the hanging-wall slates 485 feet from the vein. Work was commenced on May 1, 1894, and has progressed continuously since, with the exception of a period of about four months, when an attempt was made to unwater the old workings by means of a bore-hole to avoid flooding of the new workings from the old. It eventually became necessary to remove the water through the shaft of the old workings. This new shaft has continued to a depth of 1660 feet, having passed through the vein at about the 1200-foot level. There are tanks at the 300-foot level and at the 700-foot level. At the latter a cross-cut was run west from the station 374 feet, through slate to and beyond the vein, the foot-wall of which was reached 124 feet west of the shaft. At the 1000-foot level a cross-cut was run 69 feet west through the vein, which was here 15 feet 6 inches wide, the foot-wall being 58 feet west of the shaft. The foot-wall of the vein was

encountered in the shaft 1245 feet from the surface. Cross-cuts in the lower levels run to the westward have encountered two small veins and two dikes of light-gray intrusive rock. The first vein encountered is very persistent in strike and dip, though usually small. It has pro-



METHOD OF TIMBERING IN GWIN MINE.

FIG. 28.

duced some rich ore. The ore-shoots of the main vein are of great length, varying in width from a few inches to 20 feet. Gouge is always present on the foot, and sometimes on the hanging-wall. The slates have a tendency to swell, and are the cause of considerable expense,

but cannot be compared in this respect to some of the Amador County mines. The vein is usually banded, and exhibits a branching tendency, there being many spurs running into the hanging-wall, but few into the foot. The lenses of quartz which are characteristic of this vein frequently build up a narrow into a large vein by splicing, and sometimes by overlapping. There is some black slaty material in the vein, but less than is found in many similar mines elsewhere. Large masses of the vein quartz are found crushed by pressure and movement, and in some places the quartz disintegrates rapidly from exposure by reason of the slaking of the carbonate of lime, which occurs in considerable quantities.

The mine is systematically opened, and substantially timbered with Oregon pine. The framing of timber is mostly done by machinery. Filling for the stopes is usually obtained from the hanging-wall, and broken by machines in chambers excavated for the purpose. Where feasible, inclined raises are put into the hanging-wall, and the chambers opened out from the raise, the rock broken passing by gravity down the incline into the stopes beneath. Where the character of the hanging-wall adjacent to the vein is such as to cause the ground to cave readily, level cross-cuts are run from the stopes into the hanging-wall, and chambers opened out at a safe distance from the vein, the filling being carried to the stopes in wheelbarrows. The Gwin Mine is one of the best managed properties it was my pleasure to visit, everything being done systematically with a view to producing the best economic results. The sketch (Fig. 28) represents the method of timbering stopes in the Gwin Mine. I was told, when at the mine, that the management had under consideration the advisability of running a lateral drift in the foot-wall, and opening the mine something on the lines suggested in the first part of this bulletin, under the head of "Methods of Mining."

Geologically, the Gwin Mine presents a striking contrast, when compared with the more important mines of Amador County. Here the vein occurs in the smooth, satin-like clay slates of the Mariposa beds, which are absolutely free from the pitted appearance so characteristic of the slates accompanying the ore-shoots of Amador County, which have been fully described under the head of Amador County, and also under the head of "General Geology of the Gold Belt." The formations encountered in sinking the Gwin shaft are diabase-tuff, clay slates, and small acid dike rocks. In the lower portion of the mine, a coarse, tufaceous rock, locally but erroneously called pudding-stone, has been encountered, which has been the cause of considerable difficulty in timbering, in carrying on mining operations. It is the intention of the company to make some changes in their shaft, and to sink to greater depth. What may be developed in this property at great depth is a matter of more than ordinary interest. Its present lowest level still lacks about 1000 feet of being as deep as the Kennedy, and it is a well-

known fact that the ore-bodies in the lowest workings of the latter show no deterioration in value.——Gwin Mine Development Company of San Francisco, owners. J. J. Crawford, secretary, Spreckels Building, San Francisco; F. F. Thomas, Gwin Mine, Calaveras County, superintendent.

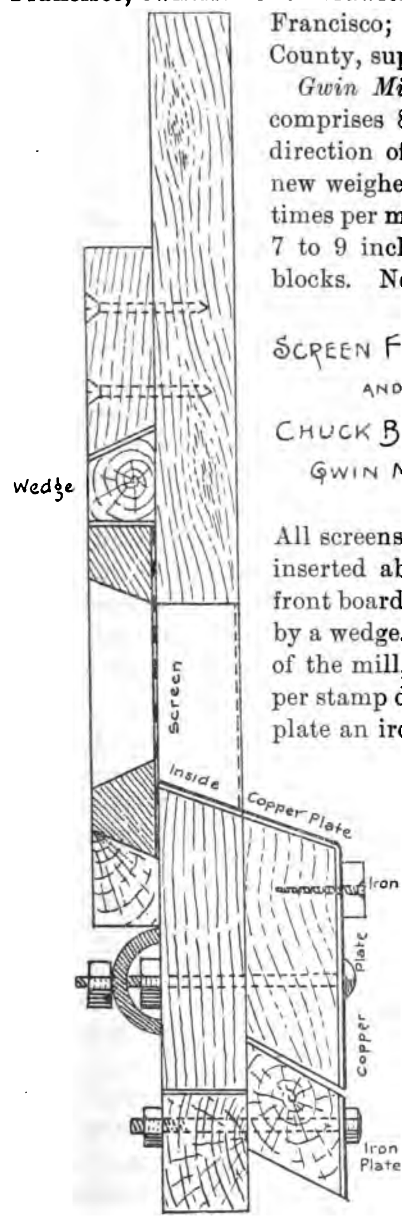
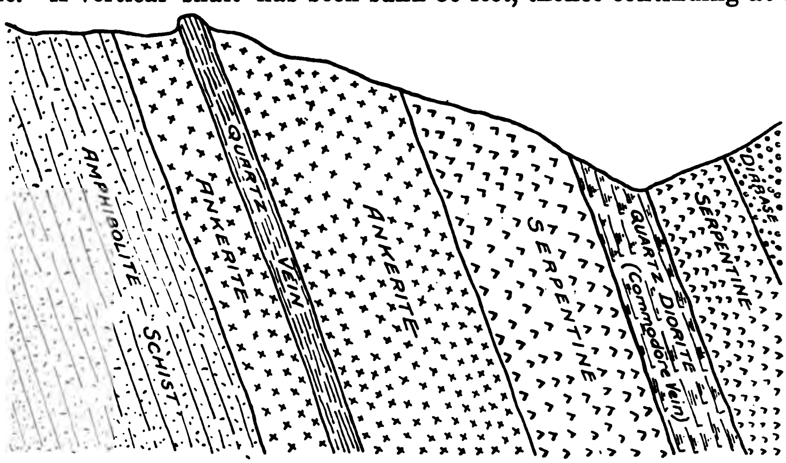


FIG. 29.

Gwin Mill.—The mill at the Gwin Mine now comprises 80 stamps, and is operated under the direction of Mr. J. E. Taylor. The stamps when new weighed 850 pounds, and drop 6½ inches 92 times per minute. The height of discharge is from 7 to 9 inches, and is regulated by three chuck-blocks. No. 16 brass wire screens are in use, and last one month. The screens are changed daily, scrubbed and dried, so that practically the screens are daily as good as new, until worn out. The size of the screen opening is 5 inches by 48 inches (discharge area). All screens are secured to small frames, which are inserted above the chuck-block and beneath the front board of the main screen frame, being secured by a wedge. (See sketch, Fig. 29.) The capacity of the mill, under the above conditions, is 4½ tons per stamp daily. To prevent scouring of the inside plate an iron rod is bolted to the plate. Its position is shown in the figure. The pulp from the battery falls onto the iron lip of the mortar, thence by a 3-inch fall onto a narrow board, and thence onto the apron plates, which are 48 x 60 inches, set at the grade of 2 inches to the foot. Thence it passes to the sluice plates, which are 24 x 120 inches, having at the end a trap for the purpose of catching mercury and amalgam. From the plates, the pulp passes to the vanner distributers, and from the vanners the tailings go to waste. In the cañon some distance from the mill a canvas plant was constructed by experimenters, some time since, but its use was discontinued. The sulphides, collected on the vanners, are heavy, probably coming from the quartz, and the values from the sulphides are largely confined to

sunk 200 feet on a vein cutting through mica schist. At the 100-foot level a cross-cut has been run east to a zone of amphibolite schist and quartz, 4 to 8 feet wide. On the 200-foot level a cross-cut has been extended 135 feet east of the shaft to this vein, which is there 8 feet wide. The mine is equipped with a 10-stamp steam mill and water hoist, but is idle. On the hill, back of the shaft, is a zone of mineralized quartz schists, which prospects in gold, and is apparently the most promising part of the property, but nothing has been done with it in the way of development.——Veritas Gold Mining Company, owners. F. J. Solinsky of San Andreas, agent.

Commodore Mine.—One mile north of San Andreas, on the Mother Lode. A vertical shaft has been sunk 80 feet, thence continuing at an



CROSS SECTION showing succession of Formations at COMMODORE MINE, 1 mile N. of SAN ANDREAS, Calaveras Co. CAL.

FIG. 31.

angle of 75 degrees to the eastward to a depth of 300 feet. A level had been run north 250 feet April 1st, developing a wide zone of mineralized rock, which in its normal condition is quartz diorite (No. 21). This occurs as a wedge-shaped intrusion, coming from the north. Serpentine forms both the foot and hanging walls of this lode. To the westward, on the Masterson claim, is a broad zone of ankerite, so frequently mentioned as occurring elsewhere, with its massive quartz outcrop and characteristic mariposite, and to the eastward of the serpentine the formation is a normal diabase. A cross-section is illustrated in the sketch (Fig. 31).

The Commodore vein is somewhat of an anomaly in this region. It is a matter of interest to know that the quartz diorite, the alteration and mineralization of which form this ore-body, is almost identical, both mineralogically and in physical appearance, with a dike of quartz-

diorite (No. 20) intruding the amphibolite schist in the Union Copper Mine at Copperopolis, in this county. On the hanging-wall side of the Commodore vein is a zone of crushed material, 4 feet in width, in which occur rhombic crystals of dolomite. These, upon being fractured, may be observed to contain visible particles of gold. The mine is equipped with a steam hoist. There are 10 men employed.——Commodore Gold Mining Company of Stockton, owners. W. H. Clarey of San Andreas, superintendent.

Illinois Mine.—It is 6 miles south of San Andreas, on the Copperopolis road, near the Demarest Mine. Since the last report it has been equipped with a steam hoist and a 10-stamp mill. An inclined shaft has been sunk to a depth of 200 feet, and two levels opened. There are two veins, one running N. 5° E., and the other N. 30° W., converging northward. The formation is clay slate on the foot-wall, and amphibolite schist on the hanging-wall. A banded vein occurs at the contact of these formations, and a brecciated gray ore in the schistose portion. Idle.——B. K. Thorn of San Andreas, owner.

Demarest Mine.—This is 6 miles south of San Andreas, near the road to Copperopolis. It is an old mine, which has been reopened since the last report was issued. An inclined shaft has been sunk to a depth of 640 feet, and still sinking in April, 1900. It has a steam hoist and a 5-stamp mill. A short shoot of very good rock has been encountered in the several levels of this mine, the formation in which it occurs being diabase. A gouge usually accompanies the vein. This, in the northern end of the mine, lies on the hanging-wall side of the quartz, on the 300-foot level. Some distance south of the shaft there is a sudden flexure of the walls of the vein, the gouge passing over to the foot-wall side of the quartz. A second shoot of what is said to be good ore is known to exist under the bed of the creek south of the main workings, but this has not as yet been reached under ground. There are 18 men employed.——The Demarest Gold Mining Company of Angels, owners. T. H. Fullen of Altaville, superintendent.

The Ford Mine.—It is three fourths of a mile east of the Mother Lode, at San Andreas. The rock formation is chiefly chlorite schist, resulting from the alteration of diorite and possibly also diabase. The foot-wall (west) of the mineral belt of the Ford Mine is a hard, dense, quartz schist, often impregnated with iron sulphide (pyrite), which is usually auriferous, though at this place to a limited extent. The hanging-wall country is greenstone schist, not materially different from that exposed in the mine workings. There are two other rocks in the mine which lie near the foot-wall. These are, first, a hard, tough, dark-green rock (No. 23), composed of an aggregate of talc scales, often schistose, and in an extreme state of alteration passes over to talc schist and massive

steatite; second, a dolomitic rock (magnesian limestone), which is also much altered and passes over to talc schist.* This rock greatly resembles the ankerite of the Gold Belt, but shows no green mariposite. These two rocks are of structural importance only, as no ore has as yet been found in them. The Ford Mine may be described as a mineral belt consisting chiefly of chloritic and talcose schists, lying upon a quartz schist foot-wall, and having a hanging-wall of diorite, locally found altered into chlorite schist. The included belt is about 100 feet in width, and within it occurs large lens-like masses of quartz, and also vein-like sheets of quartz. The former are often found mixed with a gray rock which is a portion of the greenstone. These masses of quartz and fragmentary greenstone are a common feature of many important mines of the California Gold Belt, and often constitute large and valuable deposits of gold ore; but there are many millions of tons of rock seemingly identical, which are of little or no commercial value, owing to the extremely low tenor in gold. In the Ford Mine, as elsewhere, these large deposits contain a variable percentage of iron sulphide (pyrite). The large quartz bodies range from a foot or two to nearly 100 feet in width. There is a small vein near the foot-wall side which appears to possess elements of value, but to what extent it is impossible to say. This vein has a strike west of north, dipping easterly with the main quartz bodies, but not connected with them down to the 400-foot level. This vein and the small feeders of quartz running into it have produced rock of phenomenal richness. It also contains considerable quantities of petzite (gold-lead-silver-bearing tellurium). The gold and tellurium occur, in this small vein and the stringers leading into it, in what is known as an ore-shoot—that is, the distribution of the gold in the vein appears to be chiefly confined to a limited area, apparently 30 or 40 feet in length, and having a trend along the vein downward to the north at about 35 degrees from the horizontal. Gold has been found nowhere else in this vein than along the shoot as described. A persistent characteristic of this vein is the occurrence of thin films of iron sulphide incrusting the cracks and seams of the quartz. In this vein gold was found on the surface; south of the shaft on and above the 100-foot level; in the shaft at about the 100-foot level; in a winze sunk on this level north of the shaft; and in a drift north of the shaft on the 300-foot level, where, I am informed, a $900 pocket was found. The repeated occurrence of the gold and tellurium at the points indicated, shows clearly the downward and northward trend of the ore-shoot. The mine is equipped with a steam hoist and 10-stamp mill. The mine is developed to a depth of 700 feet, and I am informed that the shaft is to

* An investigation of similar rocks, near Forest Hill, Placer County, has led me to believe that the two rocks here described represent different stages in the alteration of the same rock.

be sunk 200 feet more. There are 10 men employed.——Ford Mining Company of San Andreas, owners. D. Gutmann of San Andreas, manager.

Angels Mine.—Is in the town of Angels, and is the second mine north of the Utica, and presumably on the same vein. It comprises a group of five fractional claims. The mine was worked extensively in former years, but until a year or more since has remained idle for many years. A vertical shaft has been sunk 350 feet, and three levels opened on a zone of amphibolite schist and quartz containing gold and auriferous iron sulphide. Only the north end of the property is in operation. The ore is crushed in a custom mill. The mine is equipped with a steam hoist. There are 40 men employed; 24 in the mine.——Angels Quartz Mining Company of San Francisco, owners. O. S. Buckbee of Angels, superintendent.

Lightner Mine.—In the town of Angels, the first extension north of the Utica, and on the same vein. The Lightner is a fractional claim, on which a shaft has been sunk to a depth of 447 feet, and five levels opened. The vein consists of a zone of amphibolite schist and quartz, ranging from 10 to 90 feet in width, and is essentially the same as the Utica Mine, geologically. The gray, granular dike rock, characteristic of the Utica-Stickle Mine, which forms large masses of the best ore of that property, is also prominent in the Lightner. The mine is substantially timbered with a modification of the square-set system. The property has a good hoisting plant, air-compressors, electric machinery, and a 40-stamp mill. The mill is operated by electricity, the hoist by steam. There are 50 men employed.——The Lightner Gold Mining Company of Stockton, owners. V. W. Miller of Angels, superintendent.

The Lightner Mill.—This is a modern mill of 40 stamps, run under the direction of J. E. Reaves. It originally contained 20 stamps, but was enlarged to 40. Twenty of the stamps weigh, when new, 955 pounds, and twenty weigh 750 pounds. The height of drop of the heavier stamps is 7 inches; that of the lighter, 7½ inches. The number of drops is about 100 per minute; the height of discharge, 8½ to 9 inches. A No. 1 punched tin screen is used. The capacity under these conditions is about 5 tons per stamp daily (by car measurement). This tonnage is probably due to the peculiar character of the ore, which consists of a considerable quantity of chloritic schist and calcite, and sharp grains of quartz, which pulverize readily, the stamp cutting the softer material rapidly. The gold is mostly caught inside the battery. The apron plates are 24 by 48 inches; the sluice plates are divided and are 20 inches by 20 feet. No traps of any kind are in use. There are 20 Frue vanners—twelve 4-foot and eight 6-foot machines. The ore contains about 2 per cent of pyrite. The pulp from the batteries is divided,

but not sized, before going to the vanners. The speed of the concentrating machines is controlled by means of a cone pulley. An experiment was made on a lower discharge (at 7½ inches), which resulted in scouring of the inside plates. This was discontinued for the higher

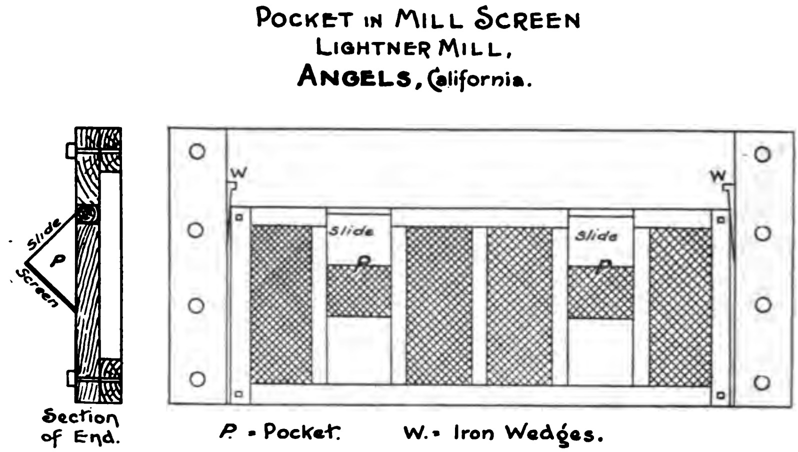


Fig. 32.

discharges now in use. Chrome shoes and white iron dies are in use in this mill. The latter last five months, crushing 750 tons of ore. The concentrates at this mill are worked by chlorination at the Utica plant. An ingenious screen has been invented by Mr. Reaves, which is illustrated in the accompanying sketch (Fig. 32). The screen is fitted with two pockets at the front, and these may be opened at will, and chips or other foreign matter removed by inserting the hand. The method of securing the screen to the frame is shown in the illustration. (Fig. 33 is an illustration of the Lightner chuck-block, with iron rods to protect the plate from scouring.)

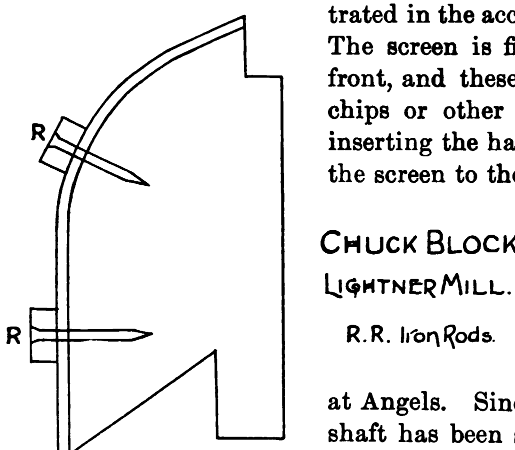


Fig. 33.

Utica-Stickle Mine.—It is at Angels. Since the last report, a vertical shaft has been sunk to a depth of 1370 feet. This shaft is located south and east of the old shafts, and is in the hanging-wall schists. It is substantially timbered throughout with heavy sets, and a large, expensive hoisting plant has been installed. This machinery sets on concrete foundations, which were constructed in the most substantial manner. For more than a year the lower levels have been flooded in the southern

part of the property. When the new vertical shaft was completed it was found that the hoisting plant, with the use of which the shaft had been sunk, was incapable of doing more than handle the water coming in at that point, and it was determined to discontinue mining operations in the lowest levels until such time as it became possible to put in a heavy plant that would economically handle both the water and ore.

The order for the new machinery was promptly placed, and it should have been in position in August, 1899, but owing to the inability of the makers, the Union Iron Works of San Francisco, to furnish necessary material, due to scarcity of iron, the great hoist was not ready for operation until early in September, 1900. During the past year or more all mining operations in this property have been confined to the upper levels of the mine.

The lower levels will now be unwatered and the large new ore-bodies discovered prior to the flooding of this portion of the mine will be worked vigorously. This property also includes the Madison and Gold Cliff mines, situated half a mile west of the Utica-Stickle group.

An extensive electric installation has been added to the Utica Company's plant. The generators are located above Murphys, on the company's ditch-line. The power is distributed to their various properties at Angels, where they also sell power and light the town. The Utica-Stickle and Gold Cliff mills are operated by this power, and also the mill of the Lightner Company, adjoining the Utica.

Gold Cliff Mine.—This is one of the Utica group, and is being operated through an inclined shaft 600 feet deep, sunk from the level of the old open cut. Four levels have been opened in this mine. The vein is found in a broad zone of amphibolite schist, with serpentine on the hanging-wall. The ore occurs in several zones, which overlap in the foot-wall going north. On the 400-foot level north of the shaft, the vein splits, being separated by a horse of diabase. Whether or not these diverging veins will re-unite is not known. The ore from the Gold Cliff Mine is crushed in the 40-stamp Madison mill. At the Utica Mine there is a 60-stamp mill, and the Stickle also has a 60-stamp mill, making a total of 160 stamps on the consolidated properties. There are 420 men employed in and about these works, distributed as follows: Utica, 125; Stickle, 90; Gold Cliff, 40; the mills, 25; chlorination and cyanide plant, 30; outside, 110.——Hayward, Lane, and Hobart Estate of San Francisco, owners. J. L. Shinn, manager. The Madison Mine has been idle for some time.

Utica Mills.—The three Utica mills are under the superintendence of W. J. Loring. The stamps of the Utica mills weigh 780 pounds; those of the Stickle, 835 pounds; and of the Madison, 920 pounds. These drop from 7 to 8 inches 105 to 107 times a minute. The height of dis-

charge in the Utica mill is 10 inches; Stickle mill, 7 inches; Madison, 5 inches. The Utica and Stickle mills are provided with No. 1 punched tin screens, and the Madison with No. 2. The capacity of these several mills will average about 5 tons per stamp daily. With the heavier stamps and low discharge of the Madison mill, it would be expected that the capacity of that mill would exceed that of the Utica or Stickle, but the Gold Cliff rock is much harder than that of the other mines.

Mr. Loring gives the following description of the Utica 60-stamp mill, and the daily routine work, together with method of making monthly clean-up, etc.:

The rock, as hoisted from the mines, is dumped at the head of the shaft over a grizzly made of 3-inch round iron bars, 10 feet long, placed 1¾ inches apart, and set at an inclination of 40 degrees. The bars are supported at each end by an iron casting, with recesses to receive them. Old stamp stems are used in the grizzly. At the lower end of the grizzly the rock passes to a Blake crusher 10 x 16 inches, being fed by gravity. One crusher of this size handles all the rock for the 60-stamp mill. One man is employed here on each ten-hour shift.

The crusher and grizzly set over a 50-ton bin, from which ore is conveyed to three bins of 200 tons capacity each in the mill by means of a dump car. The bins discharge into Challenge feeders. In the Utica mill they have made a practice of keeping on hand a new cam shaft with ten cams in place, which, in event of breaking the shaft, may at once take the place of the broken shaft. In case of such difficulty, much time is saved by this arrangement. The discharge in the batteries is 10 inches high; three differential chuck-blocks are in use, keeping the discharge as nearly uniform as possible. Manganese steel shoes are used; these are 10 inches long, 8½ inches in diameter of face, and weigh, new, 177 pounds; when worn out, they weigh but 28 pounds; their life is about 296 days. The dies are made of hard iron, and last 120 days; they are 5 inches high, 8¾ inches in diameter of face, and 9⅛ x 9½ inches base area; they weigh 84 pounds, and after using, about one half of this. Round needle punched tin screens are used in sheets 10 x 14 inches; No. 1, or 30-mesh, has been found to give the best satisfaction, and lasts from 15 to 20 days. Before using, these are burned over a moderate fire of charcoal, for the purpose of removing the tin, to prevent amalgamation of the tin. This anneals the metal, and makes it a very tough, durable screen. A splashboard made of 1 x 12 inch clear pine, having the full width of the screen, is suspended to the screen frame by two eyestraps riveted to each end of the board and two hooks screwed to the screen frame. A strip of canvas 6 inches wide is tacked to the lower end of the board, to confine the splash to the apron. Underneath the screen is bolted an iron apron, which constitutes a portion of the mortar, and being an inch below the lip of the mortar,

North Shaft and Mill, Utica Mine, Calaveras County.

The Keystone Mine and Mill, Amador City.

permits the insertion of a rough board 1 x 12 inches, which lies flush with the upper edge of the lip of the mortar. Upon this the pulp from the screen falls, and it is considered a good amalgamator. After being in use a short time, it amalgamates quickly, but does not stand the jar as well as the copper plate. A splashboard of this kind can be cleaned in one eighth of the time required to clean a copper plate. The board is protected by a 2 x 6 inch board, extending across the apron, and having a $\frac{5}{8}$-inch hole bored at each end to receive two hooks fastened to the battery posts. Four inches below the board, on the apron, runs a trough in which are two apertures 3 inches square, through which the pulp passes to a copper plate 5 inches wide, with a pitch toward the mortar, whence it passes to the sluice plates, 2 feet wide and 22 feet long, covered with $\frac{1}{16}$-inch copper plates set on a grade of 2 inches to the foot. Each battery has two separate runs of these plates, set independently, provided with wedges to adjust the grade. Before putting on the plates, the tables are dressed down in the center about $\frac{1}{16}$ inch for the full length. This causes the pulp to run in angular waves across the plate. If the tables are left plain without the center depression, it is a difficult matter to cause the pulp to be evenly distributed over the plate, as it usually flows to one side or the other. The first 8 feet of plate at the upper end of each sluice is raw copper, the remaining 14 feet being plated with $2\frac{1}{2}$ ounces of silver to the square foot. The plating is done in the works of the company. The plates are cleaned every morning.

A plug of soft wood is driven into one of the 3-inch holes of the cast-iron aprons previously described, causing the pulp to run through the trough and out of the other 3-inch hole discharging on the other plate. The plate to be dressed is first washed with clean water to remove sand, then sprinkled with quicksilver, and rubbed vigorously with a whisk-broom for the purpose of loosening the amalgam. About once a week a weak solution of cyanide of potassium is used in dressing the plate. This operation must be done with care, as the application of too much cyanide causes the plates to become glazed and brittle, when they are no longer fit for the use for which they are intended. After the plates have been thoroughly rubbed with a whisk-broom, they are rubbed downward with a piece of pure India rubber $\frac{1}{2}$ inch thick, 4 by 7 inches in area. The amalgam is then taken up, together with the sulphides which may have adhered to the plates during the twenty-four hours. The plate is then lightly sprinkled with quicksilver at the head, and lightly brushed with a whisk-broom its full length. The last plate is always brushed upward from the lower end, to place any amalgam which should be hanging to the lower edge of the plate in a position where it may be seen and collected. By this method, two men can dress twenty-four

sluices, 22 feet in length by 2 feet wide, in from one and a half to two hours.

For the purpose of saving the rich sulphurets which have adhered to the plates, and which are often worth $10 per pound, the amalgam collected each morning is cleaned in a tank used for that purpose only. At the end of the month this tank is cleaned out and the sulphurets are charged with 25 pounds of quicksilver, into an amalgamating barrel of 40 inches diameter and 48 inches long. This revolves for eight hours, at 14 revolutions per minute. The charge is taken out through the head with a dipper, is panned and settled. The amalgam is cleaned in the usual way, and the sulphurets sent to the chlorination works in a wooden bucket. At the lower end of the sluices is a tail-box, having the width of a double sluice, with a drop of 3½ inches, and a width of 5 inches on the bottom. This box has a wing its full length, with a pitch of about 45 degrees toward the sluice plates, and extends to within ½ inch of the bottom of the box. The wing causes the pulp to pass under it and keep the box clear at the bottom, catching any free quicksilver. From this opening extends a sluice 12 inches wide and 8 feet long, the upper end of which is provided with ½ x ½ inch riffles 2 inches apart, while below the riffles are 6 feet of silver-plated copper plates. This box has a grade of ⅞ inch to the foot, and from it the tailings pass to the concentrators.

Each battery has three concentrators. There are in use in the several mills of the company fifty-four 4-foot Frue, six 4-foot Union, and sixteen 3 foot 10 inches Tulloch machines. A series of comparative tests was made some time since, which showed little difference in the value of the tailings passing the machines. Mr. Loring made special experiment with several of the Frue machines. The machine has a shaking-frame 12 feet long and 4 feet wide. The back roller was dropped 3 inches by putting a block of wood between the side rail and the bearing that supports the roller. Then a number of small rollers which carry the belt were taken out, reducing the total length of the concentrator to 8 feet from the center of the head roller to the center of the small roller. The belt from the small roller to the back roller had so much grade that nothing was saved on it, so that by this arrangement of the concentrators the effect was the same as though the machines were but 8 feet long. Tailings assays showed as follows:

From the altered machine, 4 x 8 feet	$0 33 per ton.
From the unaltered machine, 4 x 12 feet	41 per ton.

This shows a saving of 8 cents per ton in favor of the short concentrator. This being the case, it would appear that a 12-foot machine is unnecessarily long. On each concentrator is a discharge, which deposits the sulphurets in a box directly under the head roller of the machine, and from this box the concentrated sulphurets are removed daily. A

car holding 900 pounds is used to convey them to the dump-house. Two samples are taken from each car with a 15-inch sampling iron, and after all concentrates for the day have been taken out and sampled, the aggregate sample is sent to the assay office, together with the aggregate of the samples of tailings, taken every three hours. These samples are assayed every day, and a record kept. The tailings from the concentrator run through a flume three fourths of a mile long, and are passed over a slimes plant of the Gates type. The concentrates from the slimes plant are conveyed by wagon to the chlorination works, where they are worked in a cyanide plant attached to that department of the works.

After a run of fifteen or twenty days, depending on the character of the ore, a general clean-up of the mills is made, as follows: The feed is shut off from three batteries until they have been "pounded out"; the stamps are then hung up, the water shut off, and two rectangular pans, 15x14 inches in area, 3 inches deep on one side and 2 inches on the other, are placed in front of each battery, the low side of each being slipped under one of the holes in the apron. These pans are made in this form to keep the upper edge as nearly level as possible when sitting on an inclined plane. The amalgam adhering to the screen frame is taken off with a scraper, and deposited in a gold-pan. The screen frame is then removed and washed; afterwards the chuck-block is taken out and placed in the clean-up room, to be cleaned; the wooden apron is then scraped and the amalgam put into a bucket; the coarse battery sands are then shoveled into a box provided for that purpose, and the pans with the cleanings from the screen frame are successively put under each stamp, which is thoroughly cleaned of any amalgam found in key-ways or between the boss-head and shoe. After each stamp has been thoroughly cleaned in this way, the amalgam is taken to the clean-up room, a check being kept on the weight of that from each battery separately. The dies are then removed and washed on the apron, and the batteries cleaned out, all the hard sand that has accumulated around the dies being put in an amalgamating barrel. After the mortar has been thoroughly cleaned, about half an inch of sand is spread on the bottom of the mortar, the dies are returned to their respective places, coarse sand packed in, and the chuck-block, which has been cleaned, replaced; the screen is replaced and keyed; the apron washed, and everything cleaned, down to the rectangular pans previously mentioned. These pans, and the buckets used around the battery, are washed into the amalgamating barrel. By the time the clean-up man has completed washing the buckets and pans, the man employed in looking after the self-feeders has started the cleaned-up battery, and has its neighbor ready to be opened. Three men on the batteries and three men in the clean-up room can clean up twelve batteries in three hours. When the

battery is first hung up, the small spreader plates are taken to the clean-up room, and the amalgam obtained is dropped into a tank, which, after the clean-up, is cleaned out and charged with other material in the amalgamating barrel.

After the mill has been cleaned up, 150 pounds of quicksilver is put into the barrel, with sufficient water to give a depth of 12 inches over the charge. The barrel is then closed, locked and sealed, and the belt put on, which drives the barrel at 14 revolutions per minute. This charge is run 30 to 48 hours. Underneath the barrel is a tank of equal capacity, from whence a sluice 22 feet long and 12 inches wide with a grade of 1½ inches to the foot, provided with silvered copper plates, conveys the pulp and water to either of two settling tanks as desired. When the barrel has run its full time, it is stopped with the head up, the head removed, and a stream of clear water under high pressure turned in, causing the slimes to come to the top of the barrel, overflow, and fall into the tank beneath, from which they pass through the sluice into a tank of 2000 gallons capacity. When the slimes have been washed out, the water is shut off. A bucket is set under the 1¾-inch plug-hole in the barrel, and the charge is drawn. The quicksilver first flows out, falling to the bottom of the bucket. A stream of water is kept running through the barrel to wash the sand through the discharge hole, and the bucket is thoroughly scraped, so that the sand will overflow, leaving the amalgam in the bottom, the "iron" next, and the sand on top. The iron is taken out as it accumulates, and after it has all been collected, it is screened through a ⅛-inch screen and the screenings panned in the clean-up tank. The result is put back into the amalgamating barrel at the next regular clean-up. The amalgam from the barrel is thoroughly cleaned and squeezed through white drilling. The amalgam balls weigh from 8 to 12 pounds, and retort about 38 per cent gold. The day before the buckets are to be cleaned, the accumulations on the sluice plates are scraped off with steel scrapers made of old files turned at one end about 2 inches, and ground to a sharp edge. The first 8 feet of raw plate is scraped in this way, leaving the 14 feet of silvered plate to run six months more without scraping. Great care must be taken in scraping silvered plates, as the silver cuts easily, spoiling the plate and making low-grade bullion. The amalgam thus collected is put in a small amalgamating barrel 15 inches in diameter and 24 inches long, which is run 28 revolutions a minute, quicksilver being added, with enough water to make a thin paste of the charge. The charge is run for twenty-four hours, when it is drawn off in a bucket and cleaned in the usual way, the sulphurets being saved in the cleaning tank previously described. This amalgam yields from 28 to 30 per cent gold.

Quicksilver is fed to the battery every hour; the amount being

regulated by the value of the ore, and this must be judged by the amalgamator from examination of the board directly under the splash of the battery, where the pulp first falls from the screen. Every ounce of quicksilver that is fed into the battery is weighed and recorded at the end of each shift, and at the end of the run the amount of quicksilver thus fed furnishes a basis for calculating the probable result of the clean-up before it is made. The retorts are lined with oak wood ashes, free from dirt; the ashes are sifted through a 30-mesh screen, and made into a paste with water; with this paste, the trays and retorts are lined, and the head thickly sealed. The ashes do not shrink like clay, to which it is superior in many ways.

The mortars in the Utica mill are of an old-fashioned type, not having been provided with liners. After being in use several years, it was found necessary to do something if the life of the mortars was to be prolonged, as the ends were badly worn just above the dies The stamps were set 10 inches between centers, using 8½-inch shoes, leaving a space of 1½ inches between each two shoes. The 9-inch dies up to that time had a life of 59 days, and the chrome steel shoes were being used 191 days. In order to line these mortars, Mr. Loring reset the stamps, using a guide with 9¼ inches between centers, and leaving ¾ inch between stamps. In this manner 1½ inches were gained at each end of the mortars, allowing room for an end liner, which served to key the front and back liners. The back was filled with wood, carefully fitted in place with the liner, saving considerable weight of unnecessary iron. The back liner is 13 inches high, and stands at an angle of 77½ degrees, the foot being 1½ inches from the base of the die. These dies are made with 8¾-inch face, while the shoes have but 8½-inch face. It is claimed by Mr. Loring to give better results than when both shoe and die are of the same diameter.

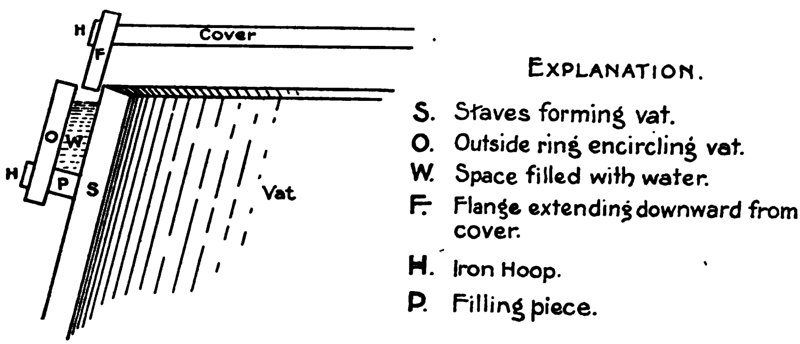
The chuck-blocks are made of wood covered with copper, ⅛ inch thick and 8 inches wide, the full length of the battery. In the center the copper is bent to fit the wooden block, the upper half being set at an angle of 45 degrees, the lower half standing vertically. At the lower edge of the block, and projecting ¼ inch over the copper, is bolted a ½ x 1 inch iron strap the full length of the copper. At the bend in the copper, or about 2 inches above the bottom iron, is bolted a second iron strap, ½ x ⅞ inch, the full length. The bolts holding these iron straps are countersunk, and the iron bars act as a protection for the amalgam which accumulates between them, and it has also been found to prevent the scouring of the upper section of the plate. There are used 8½ gallons of water per battery of 5 stamps per minute, and in addition 2¼ gallons per minute outside for each battery.

All chips, shoe wedges, and other wood used about the mill, are saved and burned in a 5 x 8-foot furnace constructed for that purpose.

The furnace has a cement floor; above it are placed grate bars to the full size of the furnace. The furnace measures from cement floor to top of bars, 15 inches; from the top of bars to the top of the arch, 5 feet; at the top of the furnace is a charging hopper made of cast-iron, with a door to fit it. When the charge has been burned, the ashes are removed and screened to remove nails, etc., that may be in the charge. The ashes are put in the amalgamating barrel with 10 pounds of quicksilver, and ground for six hours sharp, as a longer time would probably cause the charge to "flour." From 6 ounces to 2 pounds of amalgam is obtained by this method every month. All the cleanings from the mill are put into this barrel and ground for such time as the case may require. In this way many thousands of dollars are saved around a large plant, by care. The amalgam from the chuck-blocks is ground in an iron mortar 12 inches in diameter, the muller of which has a connection made in such a way that it can be stopped or lifted as desired. It will grind a charge of 14 pounds, and has a speed of 65 revolutions per minute. The labor employed in the mill is as follows: One man to each shift of twelve hours, whose duty it is to look after the feeding of the batteries; one night amalgamator, who attends to the amalgamating and looks after the mill generally; one concentrator man on each twelve-hour shift, who attends to 36 concentrators; one day amalgamator and helper, who attend to the amalgamating and general repairs about the mill; one superintendent, who has charge of everything connected with the mills and plating works; thus seven men, besides the superintendent, operate a 60-stamp mill. Owing to the fact that the company own their power, against which they make no charge for the plant or deterioration, the cost of milling at the Utica mills is very low, being, before the recent rise in the price of iron, about 14 cents per ton.——W. J. Loring, superintendent, Utica Mills.

The Utica Chlorination Works.—This plant consists of seven furnaces, having a daily capacity of 29 tons. F. C. Beedle is superintendent. Four of the furnaces are in constant operation. They are 72 x 13 feet, and have a capacity of 4¾ tons each daily. The material treated in these furnaces is iron sulphide, concentrated from the Utica-Stickle and Gold Cliff ores. The tanks are made of redwood held by ⅝-inch round iron rods, each in three sections and secured with screw clamps. This method of clamping tanks draws the staves evenly, secures great firmness, and renders the tanks perfectly water-tight. The covers of the tanks are no longer "luted" on as formerly, but are provided with a downwardly projecting flange, which drops in an annular trough encircling the tank and filled with water. The accompanying diagram (Fig. 34) illustrates this construction of the air-tight water joint. The covers are raised by means of a chain block suspended from an overhead traveler. The tanks have a capacity of 5 tons each. The pipes

from the chlorine gas generators, which latter are very large, are so arranged that when the gas is turned into No. 1 tank, having permeated the ore below, it passes from the top of No. 1 tank into the bottom of No. 2, so that there is no waste of gas. In generating gas, 100 pounds of salt and 90 pounds of black oxide of manganese are used. To this, sulphuric acid is automatically added, until it ceases to evolve gas. Liquid chlorine was at one time tried in these works, but Mr. Beedle said it was found to cost twice as much as making gas by the above described method, though otherwise satisfactory. The ore is introduced to the reverberatory furnaces containing 5 to 10 per cent moisture, in a charge of 2600 pounds. It is spread in a 2-inch layer on the first



SECTION of Cover and Top of Vat, Chlorination Works, UTICA MINE, ANGELS, Cal.

showing air tight water joint.—

FIG. 34.

hearth. After two hours it is stirred, and later it is restirred three times before being raked forward to the second hearth. On the second hearth, 40 pounds of salt are added to the charge; on the third hearth, the ore, having been thoroughly roasted, is withdrawn from the furnace, cooled and charged into leaching-vats. One and one-quarter cords of wood are required to roast 5 tons of ore.

Utica Cyanide Plant.—In this plant 8800 pounds of slimes obtained from the canvas plant are treated in eight hours. This is charged in steel tanks, and agitated 6 hours with a 5 per cent solution of potassium cyanide. The pulp is discharged into a vacuum filter, and is first washed with sump solution, and later with fresh water. The results are said to be entirely satisfactory. The auro-cyanides are precipitated on zinc shavings.

Bovee Mine.—This property adjoins the Fox or Angels Mine on the north, at Angels. It has been idle for many years.——The Marshall Mining Company, owners. E. P. Lynch of Angels, agent.

Perlina Mine.—At Altaville, northeast of the Angels Mine. It has an inclined shaft 75 feet deep, from which drifts have been run on the vein. The property has been superficially worked for years, the ore being crushed in a 4-stamp mill. The vein has never been cross-cut, and its width is unknown. As far as known at this writing, the vein has a width of from 4 to 12 feet, between two gouge seams. The formation is diabase and amphibolite schist. There are 3 men employed.——J. G. Maltman of Angels, owner.

Great Western Mine.—At Altaville. It has a vertical shaft 220 feet deep, with drifts at 50, 100, and 200 feet south of the shaft, no work of consequence having been done to the northward. There is a stope at the 50-foot level and one at the 100-foot level. On the latter level, it is said the vein is from 8 to 20 feet in width. The hoisting machinery has been removed and the mine is idle.——Seifert & Baumhogger of Angels, owners.

St. Lawrence Mine (Bruner or Bald Hill).—This mine has been reopened since the last report, and an inclined shaft sunk 400 feet at an angle of 64 degrees; there is a level at 100 feet and another at 400 feet. An open cut on the surface exposes a shoot of ore 80 feet in length, which was worked down to a depth of 60 feet many years ago. The trend of this shoot is to the south, at an angle of 40 degrees; two other shoots are known to the northward. The formation is diabase and chlorite schist. The vein consists of a mixture of quartz and diabase, impregnated with auriferous iron sulphides and free gold. The mine is equipped with a steam hoist, but has no mill. The south drift at the 400-foot level had not reached the ore-shoot at the time of my visit, but drifting was in progress.——St. Lawrence Gold Mining Company of Hanford, Cal., owners. A. J. Cameron of Angels, superintendent.

Bolytho Mine.—This is 1 mile south of Angels, and has been mentioned in previous reports. It was originally worked as a pocket mine, and as such produced several thousand dollars in gold. Expensive development was then undertaken, with a view to working it as a milling proposition, but up to this time the experience of the operators has been rather unsatisfactory. The last work performed was the sinking of a vertical shaft to a depth of 300 feet; this shaft passed through a succession of formations—diabase tuff and tufaceous slate, characteristic of the Gold Belt, being most prominent. These formations are intruded by a dike of straw-colored rock, which is identical with the intrusive rock found in the Utica-Stickle, Gold Cliff, and other important mines in this section. The dike is from 30 to 40 feet wide, and carries much finely disseminated iron sulphide, which is doubtless auriferous, but to what extent is not known by the management, as no attention was paid to it, for the reason that it was not massive quartz. It is the

intention of the company to cross-cut from the bottom of the shaft to the eastward and again intersect the dike, which is, undoubtedly, whatever its value may be, the main ore zone of the mine. When this is done, long drifts will be run for the purpose of prospecting. Geologically, this mine possesses many of the features common to the best mines of this section. In addition to this shaft, an inclined shaft has been sunk 300 feet on a west vein, and thousands of feet of drifting and cross-cutting have been done in the upper portions of the mine in search of pockets and pay rock. The vertical shaft is equipped with a steam hoist.——Bolytho Mining Company, Appraiser's Building, San Francisco, owners. E. P. Lynch of Angels, superintendent.

Big Bonanza Mine (Harris or Oriole).—It is 1 mile south of Angels, and has been developed by a vertical shaft, which was 425 feet in depth May 1, 1900. A level has been run at 130 feet, 60 feet southeast, and another at 200 feet. The formation in which this mine occurs is augite diorite, in which occur fine-grained phenocrysts of hornblende and augite. This rock near the vein is altered to chlorite schist. The vein consists of a zone of quartz and schistose rock, dipping 75 to 80 degrees to the eastward. The mine is equipped with a substantial steam hoist, but has no mill. There are 15 men employed. Sinking is in progress. It has been recently reported that 30 feet of ore has been developed on the 400-foot level, 5 feet of which is high grade.——Oriole Mining Company of Stockton, owners. John H. Heard of Angels, superintendent.

Drake Properties (Ltd.).—These are a mile southeast of Angels. Two shafts have been sunk—one 900 feet, the other 300 feet—vertically for the purpose of prospecting. The formation is diabase and black tufaceous slate, the latter being cut by a small dike with quartz and pyrite. Idle.——Drake Properties (Ltd.) of London, owners. F. J. Solinsky of San Andreas, agent.

Tulloch Mine.—It is 2½ miles south of Angels. After a long idleness it has been reopened and sinking is in progress in the shaft, which September 1st was down 250 feet. Steam hoist. There are 12 men employed.——Mr. Blevin of Angels, superintendent.

Relief Mine.—It is 1 mile south of Angels. It has a cross-cut tunnel 165 feet long, and a winze sunk on a zone of schist 90 feet below the tunnel level. The mine has no machinery. Idle.——Bonded to San Francisco company. Mr. Hogarth of Angels, owner.

Melones Consolidated Mines.—This group of mines is on Carson Hill, reaching from the summit of that eminence to the Stanislaus River, and embraces seven claims extending along the lode for a distance of a mile. The claims are the Reserve, Last Chance, Melones, Enterprise, Mineral Mountain, Keystone, and Stanislaus. These mines were among the first worked in the county, and the several claims have been

developed to depths varying from superficial, though large cuts, to shafts 300 feet or thereabouts in depth. The development undertaken by the present owners consists in an extension of the South Carolina tunnel. (This property adjoins the Melones Consolidated on the east.) It was run through the Enterprise and Reserve ground under the large open cuts on the surface, and connection established. It is 621 feet below the collar of the Reserve shaft. This development has exposed large veins of ankerite and quartz with amphibolite schist, all of which is gold-bearing, with auriferous sulphides. To what extent these great veins are auriferous is of course a very important factor, viewed from the commercial standpoint. The values vary greatly, ranging from many thousands of dollars per ton to a mere trace of gold. Large samples taken systematically from cross-cuts on the veins show values varying from \$1.50 to about \$9, the greater portion running from \$2.50 to \$3.50 per ton, though some portions average better than this, according to statements made by the management. A new tunnel (designated as No. 3), 6 feet 6 inches by 9 feet clear, was started to run under the South Carolina tunnel about 200 feet lower. This tunnel is now in about 3500 feet, and judging from the character of the formation passed through in the last 100 feet is nearing the vein. The tunnel cuts diagonally across the formation, and is being driven through the foot-wall country. It is perfectly straight, has a double track throughout, and is a creditable piece of mine engineering. Machine drills are in use, the compressors being situated near the mouth of the tunnel. There are still several hundred feet to run before this tunnel reaches a point beneath a winze sunk from the South Carolina tunnel. A raise of 65 feet from the new tunnel will make this connection at a point 1000 feet below the cropping on the summit of Carson Hill. The grade for a 120-stamp mill has been completed, and a large amount of machinery is on the mill site. The first attempt to construct a dam across the Stanislaus for the purpose of furnishing power for this property was a failure, and a new site was chosen a few feet higher up the stream. This is about 2½ miles above Robinson's Ferry. The dam is being put in at this writing (September 1, 1900), and it is stated that no obstacles to its successful construction have been encountered thus far. The water diverted by the dam will be conducted by ditch and flume to a point opposite the mill site, and it is calculated to furnish power for the entire plant. This is one of the largest mining operations in the State, but much still remains to be done before it can be placed on an operating basis.——Melones Consolidated Mining Company of Boston, owners. W. C. Ralston of Robinson's Ferry, manager.

Last Chance Mine.—Near the town of Angels, on the southern limits. Nothing has been done here since the last report. It has an inclined shaft 73 feet in depth.——G. C. Tryon of Angels, owner.

San Justo (Carson Creek) Mine.—The work in progress May 1, 1900, is in a south drift on the 250-foot level, where a new ore-shoot has been discovered. The mill, which had long been idle, was started up May 1st, and the chlorination works one month later. The mill has 40 stamps; 40 men are employed.——The San Justo Mining Company, Parrott Building, San Francisco, owners. V. W. Miller of Angels, superintendent.

Greek Mine.—Near the road between El Dorado and Railroad Flat, 20 miles from San Andreas. It is developed by a shaft 170 feet deep, with a drift 120 feet long at the 100-foot level. The vein cuts vertically through mica schist, and has the remarkable accompaniment of two dikes—the older a dark-green, hard diorite; the later, a light-colored, finely grained dike of acid type. The latter is usually found in contact with the vein, which is either banded or massive, showing in places coarse gold. The general tenor of the ore, however, is low grade. It is equipped with a steam hoist and a 5-stamp mill. Idle.——Greek Mining Company of San Andreas, owners. F. J. Solinsky of San Andreas, agent.

Ritter Mine.—This is 1½ miles north of Mountain Ranch, or El Dorado. It is opened by a tunnel 410 feet in length, driven on a small vein of granular quartz having a peculiar schistose structure. The rock is extremely hard and flinty. One shoot of ore developed by this tunnel and a raise produced considerable high-grade specimen rock. The vein strikes N. 30° W., and is intersected by a larger quartz vein, striking north and south and dipping 65 degrees east. This vein is dislocated by the smaller vein a distance of 40 feet. A small force was at work in the spring of 1900.——Rodesino Estate of Mountain Ranch, owners. Bonded to S. Redmond of San Andreas.

Blue Jay and Yellow Hammer Mines.—These mines are 2½ miles east of Mokelumne Hill, near the Calaveras River, and comprise 3100 feet on a banded vein in Calaveras formation. The vein is from 2 to 6 feet wide, cutting mica schist and slate. It is usually accompanied by a small acid dike. The property is in the prospective stage.——F. Courtmarsh et al. of Mokelumne Hill, owners.

Esperanza Mine.—It is 2½ miles northeast of Mokelumne Hill. Developed by an inclined shaft 1000 feet deep. The property is equipped with hoisting works, 30-stamp mill, and chlorination plant of three furnaces; motive power, water. Idle in the spring of 1900, but it was said that the mine was about to resume operations.——Esperanza Mining Company, 220 Sansome Street, San Francisco, owners. Prescott Ely of Mokelumne Hill, superintendent.

Calaveras Mine.—It is 2½ miles north of Mokelumne Hill, near Big Bar bridge. It was described in former reports as the Garner. The vein,

which occurs in diorite, is opened through an adit tunnel. A vertical shaft is being sunk from the surface, calculated to reach the vein at a depth of 350 feet, and a winze is being sunk below the tunnel, 70 feet north of this shaft. The vein strikes N. of E., dipping W. 57°. The ore is crushed in a 10-stamp mill, situated on the opposite side of the Mokelumne River, in Amador County, power being furnished by a turbine wheel, using about 1200 inches of water. The mill runs during the day only. At the mill an air-compressor furnishes power for drills used in the mine on the other side of the river. There are 24 men employed. ——Calaveras Gold Mining Company, owners. Peter Houghton of Mokelumne Hill, superintendent.

North Star Drift Mine.—This is 2 miles south of Mokelumne Hill, on the Old Woman's Gulch blue lead. The channel has been reached by means of a cross-cut tunnel, in 1360 feet March, 1900. This tunnel is 6½ x 10½ feet. Nine men are employed, there being as yet no machinery.——North Star Mining Company, owners. P. Schuman of Mokelumne Hill, superintendent.

Ellen Vannan Drift Mine.—This is half a mile below the North Star Mine in Old Woman's Gulch, and on the same channel. It is opened through an inclined shaft 195 feet deep. Six men are employed.——W. J. Jackson et al. of San Andreas, owners.

Green Mountain Mine (Hydraulic and Drift).—This mine was being operated by hydraulic process with success during the spring of 1900, under permit of the United States Débris Commission, employing 12 men during the day only. From a portion of this claim there have been shipped, within the past two years, 12 tons of quartz crystals, for which this mine has long been famous. These were placed with Tiffany & Co. of New York, who estimated their value at about $18,000. Several handsome and absolutely perfect crystal spheres have been cut from the crystals obtained in this mine, but the limit of the size of a perfect sphere has thus far been about 5½ inches. A statement was made to the writer by one of the owners, that Mr. Tiffany had said that if a crystal could be obtained which would cut a sphere 7 inches in diameter, which should prove to be absolutely faultless and without a flaw, such a sphere would have a valuation of $30,000.——J. E. Burton et al., owners. J. McSorley of Mokelumne Hill, superintendent.

Emery Hydraulic Mine.—Also known as the Rose Hill. One mile from Mountain Ranch. This mine is situated on a branch of the Fort Mountain channel. It was being operated in the spring of 1900 with 800 inches of water, and two monitors working twenty-four hours daily, two pits having been opened. No work was in progress in the south pit. The work in the north pit is being carried down stream, a long tunnel having been cut for drainage. The water pressure at the upper

pit was 300 feet, at the lower pit 400 feet. The company owns 2½ miles on the line of this channel. The bank has averaged thus far about 20 feet in height. From 2000 to 2500 yards are moved every twenty-four hours, when a full head of water is available. The owners have spent a large sum of money in perfecting their water-system, consisting of reservoirs, ditches, pipe-lines, etc. In the mine 10 men are employed; 15 on other work.——Emery Gold Mining Company of Mountain Ranch, owners. Earle C. Emery of Mountain Ranch, superintendent.

San Domingo Hydraulic (Jupiter) Mine.—This property was being worked in May, 1900, with two giants using 1500 inches of water under 150 feet head. The average of the season is estimated to be 1.25 yards per day per inch of water employed. The bank is nearly 100 feet high; the gravel is loose, and disintegrates rapidly under the powerful streams from the giants. The flume at this mine is 4 feet in width, 3000 feet long, and set on a 4-inch grade. The company owns about 2 miles on the channel. There are 8 men employed.——The San Domingo Gold Mining Company, Parrott Building, San Francisco, owners. A. B. Thompson of Angels, superintendent.

French Hill Quartz Mine.—This is a prospect situated on the slope of the famous French Hill, about half a mile east of Mokelumne Hill. A cross-cut tunnel is being driven, which in March was in 400 feet. There are 5 men employed.——J. E. Burton et al., owners. T. E. McSorley of Mokelumne Hill, superintendent.

Satellite Copper Mine.—This property is near Campo Seco. When visited in the spring, the inclined shaft was down 250 feet, and sinking. The hoisting is being done by means of a gasoline engine, which appears to give satisfaction. At this mine an 80-ton water-jacket furnace was found in full blast, operated by what is known as "partial pyritic smelting," under the direction of E. J. Fowler, metallurgical engineer. The furnace is of special design, constructed from plans made by Mr. Fowler, in which 80 tons of material are treated daily, of which 50 tons are ore, the remainder being flux. The charge consists of raw ore, roasted ore, slag, limestone, and low-grade matte. In what proportion these are charged was not learned. Mr. Fowler says that this method of pyritic smelting is entirely feasible and successful on ores of this class. The ores are chalcopyrite and pyrite. A little zinc is occasionally seen. The ore contains but little silica, and quartz is brought from the croppings of neighboring veins for flux.——The Pennsylvania Manufacturing Company of Campo Seco, owners. A. C. Harmon of Campo Seco, superintendent.

Borger Copper Mine.—Near Campo Seco, and in the principal mineralized zone of the district. A new shaft is being sunk on a promising copper vein by Mr. C. Borger of Campo Seco.——C. Borger, owner.

Union and Keystone Copper Mines.—They are at Copperopolis, and comprise a mile of locations on the copper belt. The mines were worked extensively in former years, and produced a large amount of copper. The principal workings are down to a depth of 800 feet. The mines were closed down in 1893, and have since remained idle. They were unwatered in March, 1900, but further than this active operations have not been resumed.——Union Copper Mining Company of Boston, Mass., owners. G. McM. Ross of Copperopolis, superintendent.

Lightner Mine.—This is 2 miles southeast of Copperopolis. It has a strong iron gossan, which occurs in amphibolite schist. It is developed by several adit tunnels and shallow shafts. The ore in the oxidized zone is essentially gold-bearing, but being in the copper belt it is anticipated that in greater depth in the sulphide zone more or less copper sulphide will be found. The mine has no machinery.——Mr. Uren of Alameda, Cal., owner. Mr. Lillian of Copperopolis, superintendent.

Royal Consolidated Gold Mine.—This is in Salt Spring Valley at Hodson, 3 miles northwest of Copperopolis. Since the last report this property has been extensively developed under new management. The former operators worked a vein which dipped to the eastward at a low angle, and confined themselves to the defined limits of the walls of that vein. The quartz occurred in a series of large lenses in a dike of diabase. There are a number of nearly vertical transverse veins which come down from the hanging-wall, intersecting the flat vein and passing into the foot-wall, but, strange to say, no attention was given these steeply inclined veins by the former management. The present management, however, undertook the exploration of the mine upon broader lines, extending raises into the hanging-wall and sinking winzes into the foot, with the result that large deposits of payable ore have been developed both above and below the original Royal vein. In this mine may be seen some of the largest stopes in the State. The mine is almost absolutely dry, some of the stopes being dusty. Comparatively little timber is employed in sustaining the ground, and in view of this fact the lack of substantial pillars is the cause of comment among visitors. Although this ground is among the best to "stand" of any I have seen in this portion of the State, there is a limit to which this method of mining may be carried with safety. A system of timbering and filling must soon be inaugurated to avert disaster, as well as to recover the large ore reserves in sight in this mine. The shaft has been sunk to 900 feet from the collar, and the lateral development is extensive. The property is equipped with a large steam hoist and a 40-stamp mill. There are 100 men employed.——Royal Consolidated Mines (Ltd.), owner. J. C. Kemp van Ee of Hodson, manager.

The Royal Mill.—The mill of 40 stamps is under the direction of J. S. Shepard. In the old mill the 20 stamps weigh 850 pounds. In the new addition to the mill 20 stamps weigh 1150 pounds each. The old stamps drop 6½ inches, and the new 5¾ inches, 104 times a minute. No. 1 punched tin screens (24-mesh) are used. The discharge is 4 inches high, and is maintained closely to this by the use of ½-inch slats beneath the chuck-block. The capacity of the mill averages 3½ tons per stamp daily. The 20 heavy stamps of the mill crush about 14 tons more in twenty-four hours than the light ones. It may be interesting to state that the capacity of this mill is determined by weighing every car of ore that goes into the mill. There are 8 Wilfley, 3 Johnson, and 1 Frue concentrators. The pulp from the Wilfley machines and also that from the Frue is recleaned on two Wilfley machines. The pulp from the Johnson concentrators is also sent over the Wilfley machines. This is a very unusual arrangement of concentrating tables, but is stated to work very satisfactorily, producing clean concentrates. At present the sulphides are sent to Selby's reduction works. The company has under consideration the construction of an additional 60 stamps and a chlorination works at the property.

TUOLUMNE COUNTY.

Since the last report was issued by the Mining Bureau in 1896, Tuolumne County has been the field of unusual activity in mining operations. Encouraged by the success of the Rawhide, Golden Gate, Black Oak, Jumper, and other important properties in this county, many new enterprises were inaugurated, and during the years 1897, 1898, 1899, Tuolumne County was giving employment to a large number of men; but, as has been the case elsewhere, some of these investments have thus far proven unremunerative, and in a few instances the propositions have been abandoned permanently, though in other cases suspended operations will doubtless be resumed. A light rainfall through several successive seasons has caused a shortage of water-supply, which has also seriously affected the mining industry in this county, more so, apparently, than in the neighboring counties, for at this time mines which have been steadily operating for years are shut down owing to lack of water for power. As an offset to this unfortunate condition is the fact that several of the mines which have been in process of development are proving valuable properties, and will form welcome additions to the list of active producing mines of the county. Notable among these are the Eagle-Shawmut near Jacksonville, and the Densmore near Columbia.

There is considerable activity in the districts of smaller mines on the East Lode, and reports of good new properties in that region may be anticipated. There still remains a large territory unexplored in Tuolumne County, both on the Central Lode and on the East Belt. Besides these there are mines of known merit in the Sierras which must ere long attract the attention of capital. Passing southward from Calaveras County into Tuolumne at Robinson's Ferry, the Central Lode is found to continue in an almost unbroken line to the southern boundary of the county and beyond into Mariposa. There is a slight break in its continuity near Tuttletown, and another break of about 1000 feet between Whisky Hill and the Dutch Mine, and still another near the foot of Priest's Hill on Moccasin Creek. There may be other interruptions in its continuity, but the instances mentioned are the most noticeable. In fact, the lode is practically continuous through this county; and, as elsewhere, it is characterized by its massiveness and distinguished by the persistent occurrence of massive quartz croppings and broad zones of ankerite. Some of the most important mines on this lode are found, not in this belt of ankerite and quartz, but in amphibolite schist on the

hanging-wall side of the ankerite zone. The Jumper and Eagle mines are notable examples. The East Lode in Tuolumne County occurs in the grano-diorite and slates. An intermediate belt lies between these two lodes, in which occur numerous pocket mines in greenstone, slate, and limestone. Mines of this class are prominent in the vicinity of Sonora and near Big Oak Flat.

Bown Mine.—This is the first mine in operation on the Central Lode south of the Stanislaus River. It is half a mile from Robinson's Ferry, and 2½ miles northwest of Tuttletown. A shaft had been sunk (June 27th) to a depth of 630 feet at an angle of 64 degrees. The vein, which was being developed, is 10 feet wide and lies underneath the ankerite zone, the foot-wall being schist and serpentine. The vein has a sinuous course and a banded structure, containing gold and auriferous pyrite. The shaft is in the foot-wall, the vein being reached by cross-cuts from the shaft at 200, 300, 400, and 600 foot levels. On the 400-foot level a cross-cut has been extended 128 feet beyond the vein into the hanging-wall. The property is equipped with steam hoist and a 20-stamp mill, in which are 8 Union concentrators. There are 20 men employed.—— Bown Mining Company of San Francisco, owner. W. J. Rule of Tuttletown, superintendent.

Jackass Hill.—Half a mile south of the Bown and east of the ankerite zone are the pocket mines of Jackass Hill, the most important of which are the Karrington and Stenchfield. This property is worked by several sets of leasers, who pay to the owner a royalty on all gold taken out. The mines are reported to have been regular and large producers for several years past. James Gillis of Sonora, owner.

Norwegian Mine.—It is 1 mile north of Tuttletown, overlooking the cañon of the Stanislaus.

Arbona Mine.—It is at Tuttletown, about ¼ mile east of the ankerite zone, in greenstone schist. The vein is from 3 to 10 feet wide, and is developed by a shaft 540 feet deep, and sinking in June. A 200-foot cross-cut tunnel intersects the shaft at 135 feet from the surface. Levels are run at 100, 200, 300, and 400 feet. The ore consists of massive quartz and pyrite. The mine is equipped with steam hoist and 10-stamp water-power mill. There are 12 men employed. This mine was worked many years ago by French people, who undertook to crush the rock in arrastras, but the quartz was found too hard to crush readily, and it had remained idle for years when the present owners renewed operations.—— Equitable Mining and Milling Company of Stockton, owners. W. E. Brooks of Tuttletown, superintendent.

Rawhide Mine.—This property, 3 miles north of Jamestown, which for several years past had attracted much attention by reason of its large

and continued output, has within the past year been involved in litigation among the co-owners, and when visited very little information was obtainable, probably owing to pending lawsuits. The property was in operation, however. Usually about 100 men are employed. The surface plant consists of a large hoist, a 40-stamp mill, and chlorination works. ——Ballard, Martin & Nevills of San Francisco, owners.

Harvard (Whisky Hill) Mines.—These are a half a mile west of Jamestown, on the dolomitic zone, though the development of pay rock is principally in a zone of amphibolite schist on the hanging-wall side of the dolomite. There are two vertical shafts—one of 500 and one of 750 feet depth. These are connected by the 500-foot level from the south shaft. The veins of pay rock consist of silicious amphibolite schist of variable width up to 35 feet. The hanging-wall is amphibolite schist, hard and firm, not gold-bearing, or only slightly so; the foot-wall is serpentine. Hundreds of feet of levels have been driven in the ankerite zone, but the values are chiefly in the zone of greenstone schist. On the 500-foot level a cross-cut has been driven westward to the massive quartz vein, probably the downward extension of the "bowlder" vein seen on the surface. This cross-cut develops nothing of value. The property is equipped with steam hoists at both shafts, and a 60-stamp mill which is run by electricity. The mill has both Johnson and Dodd tables, which effect a clean concentration of the sulphides. A series of cyanide experiments is to be made, with a view to treating the sulphurets by that method. The apron and sluice plates are 6 feet wide, divided by a longitudinal strip down the center. The plates have a grade of 1¼ inches to the foot. Thirty stamps were dropping at the time of my visit. There are two electric motors in the mill, each of 75 horse-power, each motor being calculated to run 30 stamps.——Harvard Gold Mining Company, owners. J. P. Munger of Jamestown, superintendent.

Dutch Mine.—It is at Quartz Mountain, and has been in continuous operation since 1893. The shaft has reached a depth of 1200 feet, inclined at 58 degrees. There are ten levels in the mine. The development is chiefly upon a zone of ankerite and mariposite 60 feet in width, in which are many veins and lenses of quartz, bearing gold and auriferous pyrite, though in greatly varying quantities. The pay zone is usually found on or near the foot-wall side of the ankerite zone. The foot-wall country consists of amphibolite schist, gabbro, tufaceous slates, Mariposa clay slates, serpentine, and diabase. These are distributed somewhat irregularly. The hanging-wall side is principally amphibolite schist, so far as could be observed. The pay shoots appear to cross the ankerite zone from foot to hanging wall diagonally, the intervening blocks of ground being much lower in grade. There is also a noticeable series of slips in the mine, which show that the hanging-vall side of the zone has in each case been forced upward. These slips

like the schists dip easterly, but flatter than the schists. Northward on the surface the ankerite extends for a distance of 1000 feet, then disappears beneath the alluvial of the valley, but considerable rock-exposures occur farther northward, and it is observed that the ankerite vein is not continuous to Whisky Hill. There is an interval of not less than 1500 feet in which it cannot be found, though reappearing on the north side of Woods Creek at the south end of the ridge known as Whisky Hill. The Dutch Mine is equipped with a large steam hoist, the compressor and mill of 20 stamps being run by electricity. There are 54 men employed. A cyanide plant was being constructed early in July to work the sulphides concentrated from the ores.——Dutch Mining and Milling Company of San Francisco, owners. Albert Trittenbach of Quartz Mountain, superintendent.

The App and Heslep Mines.—These join the Dutch Mine, and are situated on the northern end of Quartz Mountain. The vein consists of a large mass of ankerite and quartz, with a black slate hanging and diabase foot-wall. The main shaft is down 1000 feet, equipped with water-power hoist. The mill has 20 stamps, and was in operation during midsummer. There are 25 men employed.——The App Consolidated Mining Company of San Francisco, owner.

Santa Ysabel Mines.—These occupy the southern end of Quartz Mountain, comprising several claims of irregular shape and size. The property was idle at the time of my visit, but it was reported that operations were to be resumed.——Santa Ysabel Mining Company of Boston, owner. E. A. Hardy of Quartz Mountain, in charge.

Jumper Group of Mines.—This property is situated on a low ridge half a mile south of the village of Stent, and comprises the Golden Rule, New Era, and Jumper mines. The Jumper is the principal mine, and is being systematically worked. The Golden Rule has a large amount of development, as has also the New Era, the latter chiefly through the medium of levels extended into it from the Jumper. The general structural geology of the mine is not wholly unlike that of other mines in the neighborhood. A cross-section taken in the Golden Rule in a long cross-cut gives a good general idea of the geological structure. Through the entire length of the hill the ankerite vein is prominent, with the usual accompaniment of large quartz lenses; all of this rock is very low grade in gold, however. The foot-wall country is diorite, separated from the ankerite zone by a dike of serpentine of variable width (about 100 feet). The ankerite is divided into two zones by the intrusion of a large dike of diorite similar to that forming the west country. East of the ankerite zone is a succession of diorite and diabase dikes, which in part are altered to amphibolite schist, and it is in this schist that the pay zone is found. Easterly from this the formation is amphibolite schist,

with dikes of granular diabase. This zone of schist is over 1000 feet wide. In the Jumper Mine the gold occurs in a dike accompanying the schistose zone, and in small veins and veinlets of quartz and calcite, scattered irregularly, but always within certain definite zones, the outer limits of which form the walls. The width of this zone varies from 4 or 5 to about 30 feet. In its earlier history an effort was made to work the mine by selection of the better from the poorer portions, but owing to the peculiar geological conditions obtaining the present manager deemed this method unsuited to the accomplishment of the best results, and the method of selection was abandoned for that of stoping everything between the walls. This might at first appear like an extravagant and unnecessary course to pursue, but the results haye proven eminently satisfactory. The Jumper is one of the best worked and best managed mines in the State. It is heavily and properly timbered. The walls are hard—that is, there is no trouble from swelling ground. The main shaft is down 1285 feet, and is equipped with air and electricity. Power drills are employed. There are nine levels in the mine. The mill has 60 stamps, and has no concentrators, except one for experimental purposes. There are 125 men employed.——Jumper Gold Syndicate of Glasgow, Scotland, owners. M. D. Kelly of Stent, superintendent.

The Eagle-Shawmut Mine.—This property is 1 mile north of Jacksonville, on the ankerite vein. Its distinguishing feature is the line of massive quartz outcrop which forms great, wall-like masses along the course of the vein. The hanging-wall country is amphibolite schist; the foot-wall is slate. The principal developments of the mine consist of a cross-cut tunnel driven 1100 feet through the foot-wall country to the vein, and a shaft sunk at the tunnel level to a depth of 660 feet on the vein. The ankerite zone contains veins or lenses of quartz, which carry gold in paying quantities, besides which there is a broad zone of amphibolite schist on the hanging-wall side, in which is a gold-bearing shoot. This rock contains 2 or 3 per cent of auriferous sulphide, and is one of the most important developments thus far made in the mine. The superintendent, Mr. Charles E. Uren, has introduced what appears to be an excellent system of stoping and filling in this mine. His plan is to put a long raise to the surface from a point above the tunnel level. This raise is driven at an angle of about 65 degrees above the horizon, the slope being westerly. The formation and veins dip easterly at about 70 degrees. The walls are usually firm and hard. The incline above mentioned reaches the surface in an open cut, where the rock (being barren) is suited for filling, and may be quarried cheaply. Stopes are started and mining operations continued by cutting out the ground the full width of the vein in the form of the letter "A", the base being longitudinally of the vein and the angle at the apex being no less than 90 degrees, in order that rock may readily run on the slope. The floor of this

stope is heavily stulled and covered with lagging. The winze passes directly through the apex of this triangular stope, and waste is sent down from the surface and the excavation filled. Stoping then progresses in "slices" on alternate sides of the winze or raise. These slices are from 15 to 20 feet in height, the pay rock passing down through mill-holes cut through from the level below, the ore-chutes being carried up by cribbing, keeping even with stoping operations, and the filling run in first one side and then the other, until the block is worked out. The levels below are worked in similar manner, the filling passing through the stationary loading chutes (at the levels) and across the track into the next winze beneath by use of an apron, which may be removed when desired until again required. This method demands a minimum amount of timbering and renders the mine safe as far as caves are concerned. It may be elaborated and extended from level to level and make available a large amount of ore at low cost of mining. In addition to the ore deposits above referred to there is upon the surface a zone of amphibolite schist, which contains a finely disseminated gold. Experiments have proven that this rock is amenable to the cyanide process. The mine is equipped with a 40-stamp mill, in which are 17 concentrators—Frues and Unions. The hoist is run by water power, and at present is situated near the inner end of the long tunnel. It is planned to raise the shaft to the surface. The mine and premises are lighted by electricity. Ore is sent out of the mine in long trains of cars hauled by a horse. The cyanide plant has a capacity of 56 tons daily, a percolation plant of 50 tons, and an agitation plant of 6 tons. A chlorination plant was in course of construction in July. There are 100 men employed.—— Charles E. Uren, superintendent.

Republican Mine.—It is ½ mile from Jacksonville, and comprises a group of claims on the main lode, the principal ones being the Republican and Mammoth. The principal ore-shoot thus far developed is from 2 to 8 feet in width. There remains much of the hanging-wall country to explore, however, and satisfactory developments may be expected in that direction. A tunnel has been run 750 feet through the foot-wall country of the Mammoth claim to the vein, and a shaft sunk in the tunnel 430 feet. The main shaft in the Republican is down 400 feet, with four levels opened. The company has a mill of 10 stamps at the mouth of the Mammoth tunnel, though at present operating only the Republican, the ore being hauled by wagons. The mill has 4 Frue vanners. A large air-compressor is situated at the mill, a pipe-line running to the Republican shaft for the purpose of operating air drills. The mill and compressor are run by water power, the company owning a ditch and flume several miles in length; but owing to a scarcity of water the past three years, this power has not been available during the summer and fall months. The hoist at the Republican is

run by steam. Water is removed from the mine by means of a valve bucket, which discharges automatically upon reaching the surface. This is accomplished by means of a tipple. The bucket is hoisted until it reaches a section of the skidway, which is movable, being secured in place by a strong iron rod passing through this section at a point somewhat above its center. Being brought to a state of rest, the weight of the bucket and contained water causes the tipple to move from an inclined to a vertical position, the bucket being then let down until the center pin of the valve in the bottom resting upon the floor of the water-dump causes it to discharge its contents, which flow away; a counter weight upon the tipple causes it to resume its normal position, carrying with it the empty bucket, which may then again descend into the mine. There are 22 men employed.——Republican Mining Company of San Francisco, owners. T. F. McGovern of Chinese, superintendent.

Clio Mine.—This is ½ mile south of Jacksonville. It has recently been equipped with a new steam hoist and a 10-stamp mill, the boilers (generating steam for both hoist and mill) being located at the mill several hundred feet distant down the hill from the hoist. A shaft had been sunk 170 feet about the middle of July, at which time the mine was not in operation, all the work in progress being at the mill, which was in course of construction.——J. E. Potter of Jacksonville, owner and superintendent.

Southward from the Clio, no mines are in operation on the Central Lode in this county, excepting some prospecting in one or two mines.

Golden Gate Mine.—It is 1 mile southwest of Sonora, and is one of the principal mines of this county. It has been in continuous operation for ten years, and has been a large and steady producer. The formation is amphibolite schist, striking N. 10° E., dipping to the eastward. Through this the Golden Gate vein strikes about N. 60° E. The strike is somewhat variable. The dip also varies from 35 to 65 degrees. Thus the vein does not conform in either strike or dip with the inclosing formation. At three points in the underground workings of the Golden Gate Mine I found veins of quartz coming in from the hanging-wall side of the Golden Gate vein. One of these appears on the 200-foot level, 500 feet in a northeasterly direction from the shaft. This vein is from 6 to 8 feet in width, showing no indications of value. This vein has an apparent dip to the eastward of 50 to 65 degrees. It does not cross the Golden Gate fissure, but stops at the hanging-wall. Another instance of the occurrence of a vein in the hanging-wall is found on the 300-foot level, 450 to 500 feet northeast of the shaft of the Golden Gate. Here is found a large stope with intermediate levels—one 20 feet above, the other 25 feet below, the 300-foot level. The mineral zone of the Golden

Gate Mine is here large, and the stopes are wide. At the point indicated a vein having a strike parallel with the Golden Gate fissure with a dip of 40 degrees to the northwest cuts completely through the Golden Gate fissure, passing into the foot-wall. This vein is about 2 feet in width. It shows no sign of valuable mineralization, and has not been worked, excepting where it intersects the stopes of the Golden Gate Mine.

One other instance of the occurrence of a vein of quartz from the direction of the hanging-wall is found on the 400-foot level, where a small vein about 1 foot in width intersects the Golden Gate vein, passing into the foot-wall. It is perpendicular, and cuts the Golden Gate vein near a right angle; it shows no sign of value.

On the 500-foot level the main drift diverges, the hanging-wall branch following a gouge and the foot-wall branch following a small lens of ore. Thirty feet from the point of divergence in the foot-wall branch is a cross-cut extending nearly 100 feet into the foot-wall, all in the hard greenstone, with no ore.

The principal shaft is down 700 feet, with a winze 200 feet below the 700-foot level at a point some distance northeast of the shaft. There are ten levels in the mine, three of which are above the collar of the shaft. Considerable development was in progress in these upper levels, some excellent ore being found. The property is equipped with hoist and 20-stamp mill, and has electric, steam, and water power. There are also a slimes plant and a chlorination works attached to the mine. Joseph Francis, who is foreman of the mine, has invented a simple device in the form of a swinging apron of iron for use on loading chutes, by means of which the chutes may be constructed so as to require less room than they usually do, the apron being turned upward or allowed to hang beneath the chute when not in use. The employment of these simple devices not only results in convenience, but also effects a saving of time and money. There are 70 men employed.——Golden Gate and Sulphuret Mining and Development Company, owner. J. Fisher of Sonora, superintendent.

Densmore Mine.—It is 3 miles northwest of Columbia, overlooking and partly in the cañon of the Stanislaus. The mine was discovered many years ago, but was developed in a superficial manner by the owner, who was unable to do more than assessment work on it. No one considered it of more than nominal value. Within the past two years, however, it has changed ownership a number of times, and it is being developed systematically. The formation is grano-diorite, and it is pertinent to here remark that, regardless of the prejudice in the minds of some against granite as a yielder of profitable ore-bodies, some of the deepest and best mines in California, as well as elsewhere, are in granite or grano-diorite. On the Densmore a tunnel has been driven on the vein a distance of 400 feet and a shaft sunk 400 feet from the surface, inter-

secting the tunnel. This is at present the principal development and has exposed an ore-shoot 200 feet long, 400 feet high, with an average thickness of about 5 feet. In places it is 12 feet wide. This ore, it is stated, will average $17 per ton. Some portions are heavily sulphuretted, and run from $150 to $250 per ton. Of this, former owners shipped during 1899–1900 over $26,000 worth, net. In addition to the above described development there are several other tunnels, shafts, winzes, etc. A main tunnel was being driven 200 feet lower than the one above referred to, which will deliver ore into the bin of the mill, which consists of two batteries of 2 stamps each, with one Wilfley concentrating table. A cyanide plant of 10 tons daily capacity also forms part of the equipment. Though in a rugged cañon, the mine is favorably situated for economic working, by means of adits, which will command over 600 feet of backs, and then another tunnel may be driven still lower if desired. A ditch owned by the Utica Company passes along the mountain side opposite the mine, and will afford a cheap power; and, taken altogether, it is one of the most favorably situated mines in the county. There were 20 men employed the latter part of June.——Hayward & Lane of San Francisco, owners. L. R. Poundstone of Columbia, superintendent.

Confidence Mine.—It is 12 miles east of Sonora, at an altitude of about 4000 feet, in the granite area lying east of the Calaveras formation. This is one of the most noted mines in the county, and has been worked for years, producing, it is claimed, upward of $5,000,000. The vein strikes N. 14° W., and dips east at 18° to 30°. The inclined shaft has reached a depth of 810 feet, with a winze 200 feet below the 800-foot level. The mine makes less than 60 gallons of water a minute. The vein varies from a few inches to 15 feet in thickness. The granite is much decayed from the surface to a depth of 300 feet, below which is found a hard, normal grano-diorite. A light-colored dike rock, frequently of pale-green color, due to chlorite, is usually an accompaniment of the vein. The ore is free milling, but contains a sulphide mineral difficult to concentrate. Cyanide experiments are being made on this mineral and also on the coarse sands which are separated from the tailings by means of a form of spitzkasten. Seventy per cent of the material is coarse sand, containing 95 cents per ton. The remaining material goes to a Gates canvas plant. The total loss in tailings is $1.65 per ton. The slimes below the canvas tables still contain $3 per ton. This is the material to be experimented upon with the cyanide process, but, due to its extreme fineness, the percolation method cannot be employed. The property is equipped with a steam hoist and 30-stamp mill, of which 20 were dropping. A No. 24 punched tin screen is used, the discharge being from 7 to 8 inches high. The capacity is 3 tons per stamp. There are 3 concentrators with 6-foot belts, and 4 with 4-foot belts. Tailings are run onto the canvas tables 9 hours before purifying. The experi-

ment of purifying was tried, but proved unsatisfactory.——Confidence Gold Mining Company of San Francisco, owners. N. Carmichael of Confidence, superintendent.

Black Oak Mine.—It is ½ mile southwest of Soulsbyville, on the East Lode, and includes the Black Oak, Carra, and Live Oak claims. The mine was discovered about thirty years ago, and during its early history gained little fame, but within the past five years it has come to be recognized as one of the most important mines in the State. It occurs in grano-diorite. The vein varies from 1 to 25 feet in width, and has several branches coming in from the hanging-wall side. These latter often contain heavy sulphide mineral of high grade. Thousands of tons of this class of ore have been shipped to Selby's. The deepest shaft is down 900 feet, at an angle approximately 65 degrees, the dip being westerly and the strike north and south. The vein is intersected at intervals by dikes of very hard dark-green diorite. These simply displace the vein. One at the northern end is evidently in the plane of a fault fissure, as the vein does not reappear on the north side of the dike, as in previous instances farther southward. The throw is presumed to be to the westward. If this assumption be correct, the Genevieve Mine, lying about 4000 feet to the northward, may be the real extension of the Black Oak vein. The mine is equipped with steam and water-power hoist and a 30-stamp mill. A large slimes plant also forms an important feature in the beneficiation of the ores. The ores are quartz, containing iron, copper, lead, and zinc sulphides. Pyrrhotite, a magnetic iron sulphide of bronze color, is a prominent constituent of the ores, and is characteristic of the granite veins on the East Lode. In the mill a 60-mesh screen is in use, the discharge being 6 inches high. The 30 stamps crush 35 tons daily, which is an unusually low duty for stamps in California, but is probably due to the hardness of the rock and the fineness of the screen. The management claims to be able to make a higher saving by fine crushing. There are 10 concentrators in the mill. The pulp from the batteries passes to the plates and thence to the vanners. Forty per cent of the gold is saved in the batteries. From the vanners all tailings go to the canvas plant, consisting of two floors 60 x 100 feet. From the canvas tables the pulp is elevated and sent to the cyanide vats, where it is charged by means of a mechanical device to insure an equal distribution of sands and slimes, and to prevent as far as possible the formation of channels in the charge. The pulp is treated by the percolation method for 80 hours, and then discharged through the side doors into the creek. A 60-ton tank is sluiced out in one hour with water under a 500-foot head. Sulphurets obtained from the vanners and from canvas tables are worked in a separate plant by agitation for a period of 36 hours, with an extraction of 94 per cent. The strength of cyanide solution employed on the tailings

is 0.25 per cent; that in the agitation process varies somewhat according to the value of the ore. There are 50 men employed.——Scott, Dow & Co., owners. W. P. Scott of Soulsbyville, superintendent.

Eureka Con. (Dead Horse) Mine.—It is on the East Lode, at Carters. The deepest shaft is down 1550 feet. The formation is mica schist of the Calaveras formation. The vein is from 1 to 12 feet wide, and consists of quartz and pyrite. The hoist and mill are run by water when available. The mill has 20 stamps of 900 pounds weight. There are 8 Frue concentrators in the mill. Formerly a canvas plant was operated in connection with the mill, but its use has been discontinued. A cyanide plant on the property treats 2 tons of sulphides daily. This is on concentrates from vanners. The screen in the battery is 38-mesh. It is claimed that the extraction is about 90 per cent. There are 41 men employed.——Alvinza Hayward and Hobart Estate of San Francisco, owners. E. T. Kane of Carters, superintendent.

Providence (Gloster) Mine.—This property is 2 miles southeast of Carters, in the cañon of the North Fork of Tuolumne River. Since the last report this mine has come into prominence as a rich producer. It was systematically opened during 1896–97, and equipped with hoist and milling plant, to accommodate which expensive grading and road-making were required, as the slope of the mountain is nearly 35 degrees. A mile and a half of road, reaching from the bottom of the cañon to the mine, cost $5,000. The vein occurs in the black slates of the Calaveras formation, and will average 5 feet in width in the pay shoot. The quartz contains 1½ per cent of sulphides. The shaft is down 850 feet, with six levels. The mill has 10 stamps, but was not in operation in July last. Only development work was in progress in the mine. All power is steam, water being very scarce in that locality. There are 12 men employed, though the full force is 30 when the mill is in operation.——Tuolumne County Mining Company, owner. C. A. Holland of Carters, superintendent.

Goldwin Mines.—This constitutes a group of three claims about a mile westerly from the Providence Mine, and 10 miles southeast of Sonora. The elevation is about 2000 feet. The strike is north and south, and the dip east. Geologically, the property consists of a broad-fissured zone with a system of parallel quartz veins of variable width, from 2 to 5 feet. The veins are often found accompanied by a light-colored dike. The formation is a fine-grained mica schist. The quartz vein is usually banded, and contains auriferous sulphides. A tunnel has been driven 850 feet on the vein and a shaft sunk 250 feet, in addition to which there are several short tunnels and winzes. The property is equipped with a substantial hoist driven by air, and a water-driven air-compressor. The company has constructed a dam in the cañon and built a

flume to the mill site, thus having free water-power. It is reported that this property has produced $150,000. It had been idle for many years before coming into the hands of the present owners. There are 25 men employed.——Goldwin Con. Mines, owner. W. H. McClintock of Sonora, superintendent.

Dreisam (*Easton*) *Mine.*—It is on the East Lode, at Arrastraville. The vein is from 12 inches to 3 feet in width, and is in grano-diorite. A shaft had been sunk to 300 feet in July, and still sinking. The hoist is equipped with both steam and water power. The mill has two batteries of 6 stamps each, and two Frue concentrators. The mill is to be enlarged. There are 30 men employed.——Dreisam Gold Mining Company of San Francisco, owner. W. Morehead, superintendent.

Grizzly Mine.—It is 1 mile south of Carters, on the East Lode. The vein is 10 feet in width, has a banded structure in Calaveras slate, with the usual accompanying dike. The shaft is down 750 feet, with levels at intervals of 100 feet. The mill has 20 stamps, with 8 Frue vanners. Water furnishes power for both hoist and mill. From 16 to 20 men were employed in July.——Grizzly Mining Company of San Francisco, owner. W. R. Hall of Carters, superintendent.

Big Oak Flat District.—Since the last report there has been much activity in and near Big Oak Flat. A score or more prospects of greater or less prominence have been incorporated and a large sum of money expended in their equipment and development. As is usual in such cases, some of these have proven unsatisfactory and have been abandoned, while others are still developing, with fair prospects.

Longfellow Mine.—It is at Big Oak Flat, and is generally considered as being on the East Lode, though this section is really between the Central and East Lodes. The geology of the mine as described by the superintendent is as follows: There are two veins about 50 feet apart, the foot-wall vein being 10 to 12 feet wide and the hanging-wall vein 4 to 5 feet wide. There are many stringers of quartz in the slaty zone inclosed between these two veins. The formation is slate. A shaft had been sunk to 450 feet in July last. The surface equipment consists of a steam hoist and a 10-stamp mill, with Wilfley and Frue concentrators. A 30-ton cyanide plant was in course of construction the latter part of July, and the tailings are to be treated by that method. During the dry season water for milling is pumped from the Mississippi shaft sunk on a vein in the granite of Big Oak Flat.——Longfellow Gold Syndicate of Glasgow, owners. A. P. Dron of Big Oak Flat, superintendent.

Mack Mine.—This adjoins the Longfellow on the east, and is on the same vein. The shaft is down 430 feet at 35 degrees. Four levels are opened, and the prospect is stated to be encouraging. The mine had a steam hoist but no mill in the latter part of July. There are 12 men employed.——Mack Con. Mining Company of San Francisco, owner. C. L. Lang of Big Oak Flat, superintendent.

A Gold-Bearing Zone.—This is found about 1 mile west of Big Oak Flat, and extends for more than 15,000 feet along the mountain side, and presumably could be traced farther. The formation consists of a succession of black slates and diabase tuff. A description of the *Criss-Cross* claim will answer in a general way for all of the numerous claims along this belt for a considerable distance in either direction from it. In that property the formation consists of Calaveras slates, and reefs of diabase tuff. The slates occur in zones, some of which are relatively soft and contain disseminated iron sulphides. The remaining portion of the slates is usually hard, and less highly mineralized. The slates are also intruded by dikes of diabase and porphyry. There are developed in this mine four zones of what are termed by the miners "mineral or metallic slates." These zones are separated from each other by dikes of variable width, not exceeding 20 feet. The slates strike north 30° W., standing vertical. The entire formation is intersected by seams and veins of quartz, which strike about N. 30° E., dipping southeasterly at 60° to 70°. Some of these quartz veins, small at the surface, widen to 24 inches or more within a depth of 50 feet, and carry disseminated gold, proving that these are not exclusively pocket mines, as has been supposed. These vertical veins of quartz occur at intervals of 8 to 10 feet, having approximately a parallel strike. A second series of quartz veins is found lying nearly horizontal, cutting the slates, and intersecting the vertical veins. These veins occur at distances of 4 to 6 feet apart, dipping at a low angle to the westward, thus dividing the formation into rhomboidal blocks. Frequently at the intersection of these highly-inclined and flat veins a slight dislocation may be noticed, indicating that there has been some movement of the formation since these veins were formed. The gold found in this property is, as far as known, confined almost exclusively to the zones of "metallic" slates. In that portion of the property to the northward the steeply-inclined veins have been found to carry coarse gold in considerable quantity; in fact, to such an extent that many thousands of dollars have been taken from rather superficial development by pocket-hunters. To the southward, however, the gold in the veins has been found chiefly in the nearly horizontal seams and veins, and these have all produced largely. The cause of this difference in the occurrence of the gold has not yet been ascertained, but the fact that such is the case is of interest. As a result of the operations of the pocket-miners there has been accumulated in

the different dumps hundreds of tons of material, which, to the pocket-miner, is waste, but it has been found by repeated tests that all of these dumps carry considerable value in gold. It is an established fact that the slates on either side of vertical veins carry gold for a distance of 2 feet or more from the vein. This also seems to be the case with the horizontal veins. It may be that the gold-bearing zones constitute a milling proposition, and that not only the quartz veins, but the slates as well, may be mined and milled as a whole. In this respect these gold-bearing zones bear some resemblance to the Jumper Mine near Stent, in this county, where it has been found that the most economical, and withal the most successful method of operating is to mine all the material between the walls of the zone and the milling of all such material, there being practically no waste.

MARIPOSA COUNTY.

Since the publication of the last report of the State Mineralogist, Mariposa County has taken on more active life. The Mariposa Grant, covering an area of about 70 square miles, which for many years had lain idle, has become the property of the Mariposa Commercial and Mining Company, which has undertaken the active exploration and development of at least five of the most important mines on the Grant. They are going about this in a business-like way, and the indications are that if there is any actual merit in the mines on the Grant it will be ascertained by the present operators. A hasty visit was made to this field of operation in the latter part of May last for the purpose of investigating what had been done and what was expected of these mines in the future.

Mariposa Mine.—This property, worked many years ago, it is reputed at one period with great success, but which had been idle for more than thirty years, has been reopened, and an inclined shaft sunk which had reached a depth 475 feet on May 15th. The shaft was carried down at a uniform angle, but the vein passed out into the hanging-wall at about 400 feet from the surface. In cutting a station at 475 feet, the vein was discovered in the hanging-wall. The walls are diorite-porphyrite, and very hard. The vein has little or no gouge, but generally breaks free from the walls. The center of the vein is usually massive, with a banded structure near the walls, and in some portions the entire vein shows the banded structure. It varies greatly in width, from a seam to 12 feet or more. It strikes N. 70° W., with a variable dip to the southward, which will average about 60 degrees. Several hundred feet west of the new shaft a branch breaks into the foot-wall, striking N. 50° W. A shaft, now caved and filled with water, is sunk at the point of divergence. It is said that large amounts of gold were taken from this shaft in the form of pockets by the early miners. A report of Dr. R. W. Raymond, "Mineral Resources West of the Rocky Mountains," 1868, states that the Mariposa Mine was closed at that time, for the reason that mining operations were no longer profitable, though the rock contained nearly $10 gold per ton. It has been ascertained by careful sampling of the faces of the stopes abandoned years ago, that considerable bodies of rock were left, which averaged over $7 per ton, where the vein was from 2 to 4 feet in width. During the past summer a long drift on the 400-foot level has cut through a fine shoot of high-grade ore. The mine is equipped with steam hoist and air-compressor, steam pumps, and other

necessary machinery. There are 28 men employed.——Mariposa Commercial and Mining Company, owners, 320 Sansome Street, San Francisco. J. H. MacKenzie, Mount Bullion P. O., general manager.

The Princeton Mine.—This property, situated at Princeton, 6 miles northerly from Mariposa, has also been reopened after an idleness of many years. A new inclined shaft has been sunk to a depth of 600 feet, penetrating some little distance below the old workings, very little of which are at present accessible. Near the bottom of the shaft, two fine-grained, ash-colored dikes intersect the vein at an oblique angle. They have not "thrown" the vein, simply passed through it. In the bottom of the shaft, at the time of my visit, the vein was about 4 feet in width, of beautiful banded quartz. The entire vein from the surface to the 600-foot level is inclosed in the typical clay slates of the Mariposa beds. These slates differ very materially from the black tufaceous slates so closely associated with the rich ore deposits of Amador County, and to which more particular reference is made under the head of Amador County.

At this writing, the latter part of May, nothing more can be said of the Princeton Mine, and only the future development of the property can determine its real merit. The mine has an authentic record exceeding $3,000,000 to a depth of 600 feet. In the foot-wall country, lying immediately west of the Princeton vein, there are many veins, both large and small, of gold-bearing quartz, and this section it is the intention of the company to prospect. The mine is equipped with steam hoisting plant and machine shop, and a 10-stamp mill is being erected for the purpose of testing ores from the several mines of the Grant. The central office of the mines is located at Princeton. There are 30 men employed. In the middle of September the shaft was down nearly 900 feet, the vein averaging 3½ feet in width.——J. H. MacKenzie, Mount Bullion P. O., general manager.

The Josephine Mine.—This property is about 3 miles north of Bear Valley, overlooking the Merced River, and immediately adjoins the "Pine Tree," with which its name is usually associated. This is also being operated by the Mariposa Commercial and Mining Company. The manager has placed a hoist underground, and sunk a winze 200 feet from the level of the "English" trail drift. A vigorous policy has been inaugurated, and the vein will be developed as rapidly as possible. It has been stated in numerous previous reports that the Josephine vein splits off to the westward from the Pine Tree vein; that it continues upon an independent course for a distance of nearly 15 miles, rejoining the main lode near Piñon Blanco, 3 miles north of Coulterville. A careful investigation has led to the conclusion that the Josephine vein returns to and rejoins the Pine Tree vein within a distance of 3000 feet from

where it diverges, at what is called the old Fremont shaft. The error into which myself as well as others have been led was in presuming that a line of disconnected croppings represented the Josephine vein, whereas the croppings of the Josephine are absolutely continuous, and may be traced from its point of divergence from the Pine Tree northward to where it rejoins the Pine Tree vein. The hills are covered with a dense growth of chaparral, manzanita, and greasewood, and the tracing of this line of croppings was not an easy task, though not an impossible one.

Both the Pine Tree and the Josephine veins are well exposed on the level of the English trail drift, where, taking a cross-section at a point 437 feet below the croppings at the Fremont shaft, it is found that the two veins converge on this level about 400 feet north of the point of meeting on the croppings, showing that the line of convergence is not vertical, but inclined to the northward. A cross-cut at the point where these veins converge on the English trail level, shows a body of quartz 40 feet in width, dipping uniformly to the eastward at an angle of 60 degrees. Along the drift which follows closely the Pine Tree vein, the two great veins are separated by a mere seam no thicker than a knife-blade. Northward, a mass of soft material composed of ankerite with mariposite and quartz, separates the veins by a few feet. Still farther northward the divergence is greater, and the Pine Tree vein shows a gouge 1 inch thick on the hanging-wall side of the vein. A cross-cut has been driven 25 feet eastward through a mass of crushed and highly altered ankerite to a second gouge containing fragments of this rock-mass. The gouge is from 1 to 2 inches thick, and is extremely tough, but soft. The wall beyond is polished like a mirror, and was formerly considered the hanging-wall of the vein. The material beyond the slip is identical with that in the cross-cut (crushed ankerite altering to talc). Serpentine occurs on the hanging-wall side of the vein on the surface over 200 feet distant. The serpentine approaches nearer to the vein, going northward, however, and in the tunnel driven near the Merced River, about 1000 feet lower than the English trail drift, lies on the hanging-wall side of a zone of material similar to that found in the cross-cut above referred to (the altered ankerite). The ankerite, containing mariposite, separates the Pine Tree and Josephine veins, and the material grows broader as the veins diverge, but where they are 80 to 100 feet apart and more, it does not fill the entire space between them—a gray rock, amphibolite schist, lying next the ankerite.

The Josephine vein is distinguished everywhere along its course by what may be termed its fragmental appearance. A banded structure is frequently apparent, but mixtures of quartz and black slaty material are the most persistent features.——J. H. MacKenzie, Mount Bullion P. O., general manager.

Croppings of the Mariposa Vein.

Croppings of the Louisa Mine, Coulterville, Mariposa County.

Pine Tree Mine.—This adjoins the Josephine, and is 3 miles north of Bear Valley. One of the old tunnels driven by the former operators has been cleaned out and retimbered, and a hoisting engine set up underground about 600 feet from the mouth. Here a shaft has been sunk to a depth of 300 feet below the level. Ventilation is secured by an upraise through old workings above the hoist connecting with an upper tunnel. The engine is operated by steam carried in from the boilers at the mouth of the tunnel, the exhaust passing out through the raise. Owing to the careful manner in which the steam pipes have been packed, there is little condensation in the pipes, and the temperature at the station is

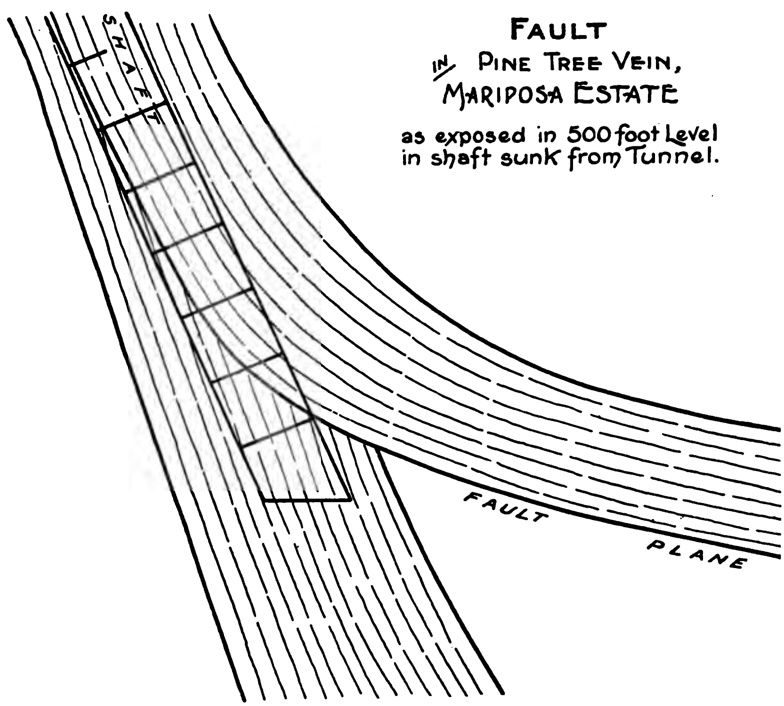


FIG. 35.

not uncomfortably warm. In sinking the shaft, a very interesting fault was discovered about 300 feet from the platform, the character of which is illustrated in the accompanying drawing (Fig. 35).

The indications are that the formation on the hanging-wall side of the fault has slipped downward, and that if sinking were continued on that portion it would be found to cut out, though in what distance it is impossible to say. The foot-wall portion, however, will extend downward to indefinite depth. The shaft is being sunk through the heart of the ore-shoot opened by the old company, it being the purpose to ascertain as quickly as possible whether payable ore still remains in the

mine, and if so, how much. The Pine Tree Mine is everywhere characterized by its massiveness and its entire freedom from slaty inclusions Iron pyrite occurs in the quartz, but is not abundant. The vein is usually well defined by smooth walls, the foot-wall being always, as far as observed, mariposite and ankerite. The hanging-wall side of the quartz vein is a granulated mass of rock, containing many fragments of what appear to be the ankerite. The real hanging-wall—normal country rock, i. e., slate, diabase, or serpentine—has not been cut on the English trail level. At the mouth of the old Pine Tree tunnel, now caved and inaccessible, the serpentine is found close to the vein. Southward, up the hill, it is fully 200 feet away from the vein. In the river tunnel the serpentine forms the hanging-wall of the vein—that is, it lies on the hanging-wall side of the fragmental rock (crushed ankerite) referred to as occurring on the hanging-wall side of the quartz on the English trail level. In the river tunnel the Pine Tree vein splits up and makes good-sized quartz veins in this fragmental material. In places the quartz is confined to the foot-wall side, ranging in width from 4 to over 40 feet. In speaking of the vein the entire mass of ankerite with the included quartz lenses is meant, though commercially only that portion containing pay ore would be recognized as the vein.

Roma and Sierra Blanca (Quartz).—Three miles northeast of Colorado. A tunnel is being run 1400 feet to reach the vein. It had reached a length of 915 feet September 1, 1900, and is being driven through soft slate and schist at a cost of $4 per foot, including timbering. All work is by hand, and the tunnel is 5 by 7 feet clear. The timbers are obtained on the property. There are 12 men employed. ——Lew Aubury of Mariposa, superintendent.

Mary Harrison.—This mine is on the southern portion of the Cook Estate, 2 miles south of Coulterville. It is situated on the great Dolomitic vein, the quartz occurring on the foot-wall side, being 4 to 6 feet wide. Both hanging and foot walls are diabase. Black clay slates (Mariposa beds) and serpentine also occur in the immediate vicinity of the vein. The deepest workings are down 900 feet, and still sinking in July last. The ore-shoot is stoped from the 700-foot level to the surface. The lower levels are extensive. A 40-stamp mill built on the Potosi Mine, one of the group owned by this company, crushes ore from the Mary Harrison Mine, with which it is connected by 4 miles of narrow-gauge railroad. No rock was being crushed at the time of my visit. Hoisting is done by steam. There are 75 men employed. In addition to the Mary Harrison, the company also owns the Louisa, Margaret, Potosi, Malvina, and numerous other claims on this large estate, but the above described is the only one in operation.——Merced Gold Mining Company of Boston, owners. J. Mills of Coulterville, manager.

Bonanza Mine.—It is 5½ miles south of Coulterville, near the Merced River, on the Dolomitic vein. A cross-cut tunnel was in 280 feet in July last, running to intersect the vein, which was said to be 50 feet in width. The hanging-wall is slate and the foot-wall serpentine. A 20-stamp mill was in process of building, and a dam was being constructed in the Merced River for power. There are 25 men employed. ——T. P. Brisland of Coulterville, manager.

Murphy Mine.—It is 3½ miles south of Coulterville, on the main lode, having serpentine on the hanging-wall and slate on the foot, differing in this respect from the Mary Harrison, which it somewhat resembles otherwise. A shaft had reached a depth of 145 feet the middle of July, and two levels had been started. The property is equipped with steam hoist, but has as yet no mill. There are 18 men employed.——The Guffy-Galey Gold Mining Company of Pittsburg, Pa., owners. W. W. Elmer, superintendent.

Black Hill (Pumpkin) Mine.—It is 1 mile north of Coulterville, and is in the prospective stage, a shaft having been sunk 60 feet, equipped with horse-whim. Some rich ore has been found in recent development. There are 5 men employed.——John Boyd, owner. J. J. Dolan of Coulterville, superintendent.

Yosemite Hydraulic Mine.—It is 10 miles east of Groveland. The company has built 11 miles of ditch flume and pipe-line the past year, and made preparations to carry on hydraulic mining on an extensive scale; the scarcity of water, however, has affected operations seriously. When working full force 20 men are employed.——W. J. Pender of Groveland, superintendent.

MADERA COUNTY.

As it was necessary to pass through Madera County in going into Mariposa, a brief examination of two mines was made while in that county. In the neighborhood of Grub Gulch prospecting is actively being prosecuted, and also in the direction of Coarse Gold, but lack of time precluded visiting that section the past season.

The Rex Mine.—This is a new property at Grub Gulch. It has been opened within the past few months. An inclined shaft has been sunk

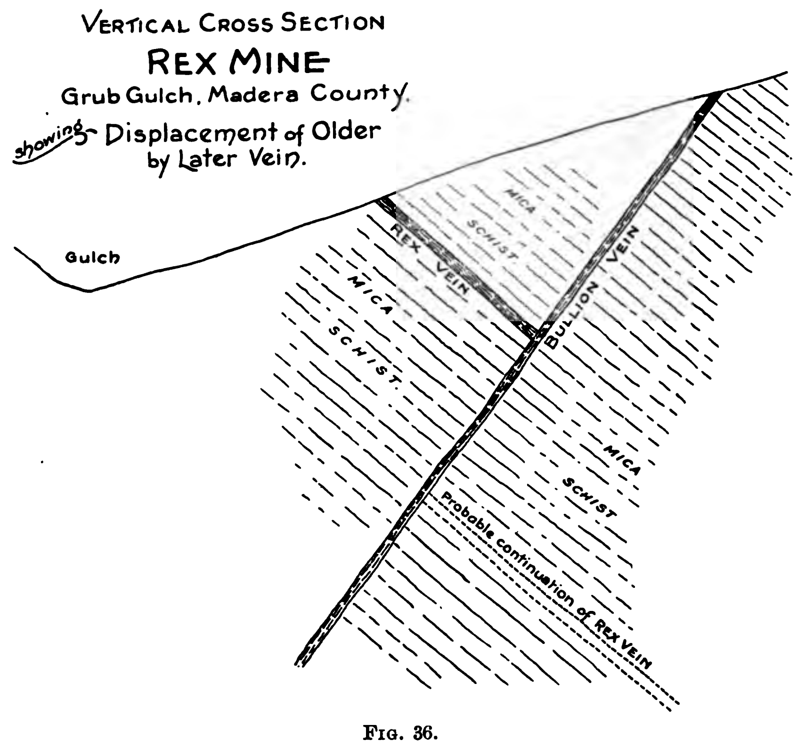


Fig. 36.

to a depth of 100 feet at an angle of 40 degrees to the eastward. At a depth of 50 feet from the surface in this shaft, the Rex vein, which is from a few inches to 14 inches in width and rich in free gold, was found intersected by another vein, known as the Bullion, which dips to the westward at an angle of 60 degrees, cutting the dip of the formation nearly at right angles and displacing the Rex vein. The formation in

which these veins occur is mica schist. That portion of the Rex vein in the neighborhood of the shaft has been opened by a series of shallow pits, and by means of these the direction of its strike can be traced along the surface. After passing the Bullion vein, which in strike intersects the Rex vein at a low angle, the Rex vein does not appear in line with the croppings on the farther side of the Bullion vein. However, farther to the northward is a vein which has the physical characteristics of the Rex vein, and also carrying the same character of gold, and this vein has been traced for more than 1000 feet from its intersection with the Bullion vein, on the opposite side of which it can be no further recognized. There is little doubt that these two disconnected veins are identical, having been dislocated by the later Bullion vein. The accompanying sketches (Figs. 36 and 37) illustrate this occurrence. As

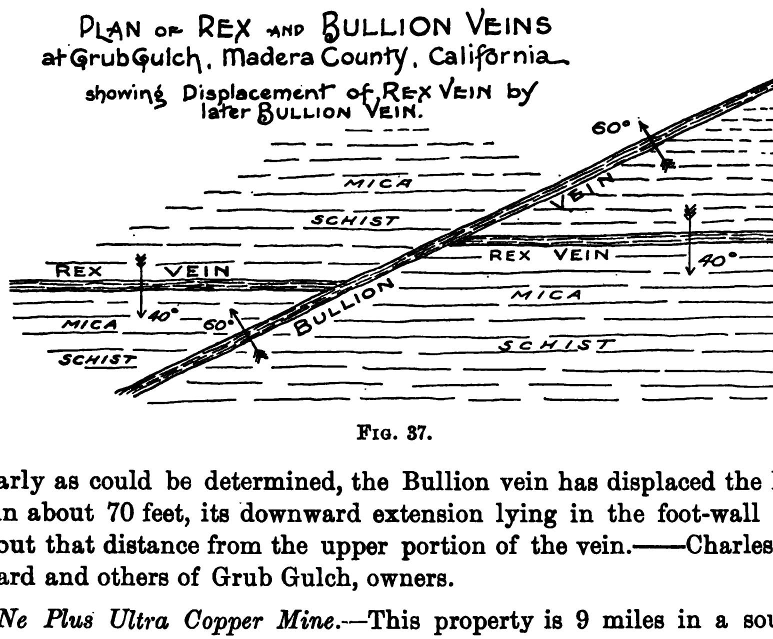


FIG. 37.

nearly as could be determined, the Bullion vein has displaced the Rex vein about 70 feet, its downward extension lying in the foot-wall and about that distance from the upper portion of the vein.——Charles M. Ward and others of Grub Gulch, owners.

Ne Plus Ultra Copper Mine.—This property is 9 miles in a southwesterly direction from Raymond, on the San Joaquin plains at Daulton. It is an old property which has been reopened since the publication of the last report. Three shafts have been sunk on the mine, 125, 140, and 145 feet respectively. These are distributed along the vein for a distance of 1000 feet. The formation is chiastolite schist. The zone of mineralization is 100 feet or more in width, in which there are several shoots of ore having an approximate parallelism with many ramifying branches. There are also dikes cutting the formation. The ore normally is an iron-copper sulphide, but in the zone of semi-oxidation, between the thoroughly oxidized gossan ores and the normal sulphide ores, oxidation is taking place very rapidly. This oxidation results in giving

out a large amount of heat, which occasions the mine workings to be unusually hot. The ore taken from certain shoots in this mine, when delivered on the dump, frequently takes fire within a few days by spontaneous combustion, and on several occasions has set on fire the cars in which the ore is transported to the smelter at Madera. A large dump situated at the south shaft has been burning for some time, and the ore now presents the appearance of an ore-pile which has been heap-roasted in the usual manner. In this mine was observed one of the very few underhanded stopes in the State. The method of working this mine illustrates to a marked degree the unfortunate policy commented upon in one of the first paragraphs of this bulletin, that of demanding immediate returns from development of ore. There are 40 miners employed in the mine, 15 on top, and 60 at the smelter, which is located near the town of Madera. The smelter was not visited.——California Copper Company of 31 Nassau Street, New York, owner. Wm. Davidson of Daulton, superintendent.

Several *copper mines* are being worked on Green Mountain about 10 miles northwest from Raymond, and there is one near White Rock, about 15 miles southwest of Mariposa. These mines are shipping high-grade, partly oxidized ores. They were not visited.

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